Modeling of Ship Maintenance System Based on Arena

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***Abstract*—Maintenance decision is an important research area for Prognostic and health management. This paper mainly studies the maintenance decision part. Taking the ship's maintenance and support system as a prototype, considering the weather, the abilities for maintenance, the supply time, and the enhancement project, a model of ship maintenance system based on Arena is constructed. The model can help arrange a maintenance plan for the enterprise to provide a reference for cost savings by refining the data.**

Keywords- PHM, maintenance decision, maintenance time, ship

I. INTRODUCTION

Prognostic and Health Management (PHM) is a comprehensive technology for fault detection, isolation, prediction, health management and maintenance decision [1]. It first appeared in military equipment and has been implemented in aircraft, space vehicles, ships, and other stuff. The application of PHM technology in F-35 in the U.S. military caught the attention of the world [2-3]. Integrated Vehicle Health Management (IVHM) integrates the system state detection, fault diagnosis and fault repair of the aircraft [4]. Vehicle Health Management System (VHMS) is an important method to improve the combat effectiveness of vehicles and reduce the costs of the whole life cycle [5].

PHM system includes signal processing part, fault diagnosis part, fault prediction part, and maintenance decision part [6]. The system structure diagram is shown below.

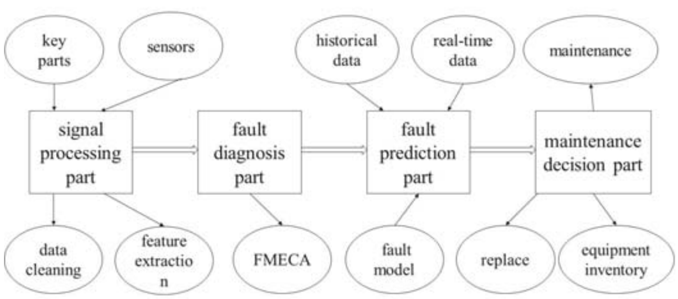

Fig. 1 Composition of PHM system

PHM system has the following advantages: firstly, real-time data collection of system operation is realized to provide references for design, evaluation, and demonstration of follow-up equipment. Secondly, through the prediction of the intelligent system, the PHM system can give real-time warning of the failure to reduce casualties and equipment damage. Thirdly, it can reduce unnecessary inspections and save costs. Lastly, it helps to arrange the purchase of spare parts through the forecast to shorten the maintenance time.

PHM technology can be characterized as "predictive maintenance" in contrast to traditional regular maintenance. Through real-time monitoring of the system status, the given model and computer processing, it can predict the remaining useful life (RUL) of the system and other relevant information. Moreover, it can generate maintenance decisions based on the expected data, and guide the development of equipment maintenance activities. The determination of maintenance time is an important part of the maintenance decision.

Ships are the leading equipment of a modern navy, and the determination of ship maintenance time is of considerable significance to maintain equipment performance, improve combat readiness and reduce maintenance cost. In the past, the mode of ship maintenance was mainly regular maintenance, which was based on the life profile of the ship and expert experience. With the change of Chinese navy's target from coastal defense to offshore defense and the increasing of ocean-going escort missions in the Gulf of Aden at the present stage, the original regular maintenance is not enough to meet the needs of ships, and then the concept of PHM is proposed. There are numerous types of research on PHM technology in ships. By collecting and extracting vibration signals of the diesel engine, the fault diagnosis system is achieved in Massachusetts Institute of Technology (MIT) [7]. This paper mainly studies the maintenance decision part. During the maintenance process, if there is bad weather, the maintenance will be suspended, which will affect the maintenance time. The level of equipment familiarity with the maintenance manufacturer will also affect the maintenance effect and time. The supply of maintenance equipment will directly affect the maintenance process, thus affecting the maintenance time. The repair time is increased when the repair is identified as exceeding the repair expectation. We established a prediction model based on Arena considering these four factors, namely

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the weather, the abilities for maintenance, the supply time and the enhancement project.

The current class of ships' maintenance is mainly made up of four categories, meaning dock maintenance, minor maintenance, medium maintenance, and major maintenance. Dock maintenance mainly means that ships are regularly docked for repair and maintenance, to remove ship rust and carry out equipment maintenance and troubleshooting. Minor maintenance mainly refers to the maintenance of the ship body and various equipment after the ship has sailed for a certain number of years. It aims to keep the ship in good condition until the next medium or minor maintenance. Medium maintenance mainly refers to the more comprehensive overhaul and overhaul of the ship after several dock maintenances and minor maintenances, to maintain or restore the tactical and technical performance of the ship. The major maintenance mainly carries on the comprehensive inspection and maintenance of the ship body and each kind of equipment. The goal is to restore the ship's technical performance [8]. For different maintenance classes of ships, the maintenance time varies significantly due to various maintenance tasks. Also, with the increase of combat mission, the first mission profile is no longer suitable for ships at this stage. Therefore, it is urgent to determine the maintenance time according to the contemporary use of ships.

The reminder of this paper is organized as follows. The second part of this paper introduces the target and makes the decision variable analysis. The third part presents the simulation model construction. The fourth part carries on the quantitative analysis of the influence factor. The fifth part summarizes the article and points out the future research direction.

II. Target and Decision Variable Analysis

Numerous factors affect ship maintenance time. According to the analysis in the introduction, we get the weather, the abilities for maintenance, the supply time, and the enhancement project as the main factors. Based on these factors, a time prediction model is established in this paper to predict the ship maintenance time and provide decision support for arranging ship maintenance plan.

The weather mainly refers to the extreme weather, especially the influence of a typhoon on the maintenance time. Ships run on the sea. And the ship maintenance shops are built along the coastline to save cost and improve efficiency. China's coast is 18,000 kilometers long, and coastal areas are often affected by typhoons. Ship maintenance shops are no exception. From June to November every year, hurricanes formed in the Pacific Ocean have a significant impact on the southeast coast of China, and October is the "high-risk period" with profound implications [9]. If the ship is repaired at this time, it may be suspended for some time due to the typhoon.

The abilities for maintenance refers to the ability of manufacturers. It includes the integrity of maintenance tools and the proficiency of maintenance operations. Different manufacturers have different completion time for various maintenance tasks.

The supply time for maintenance refers to the supply of equipment needed in the maintenance process. The equipment required varies according to the parts to be repaired. Conventional equipment generally has more inventory, and it does not have a more significant impact on the maintenance time. Critical components of the machine usually have less inventory. The manufacturer is required to order according to the maintenance content. Therefore, the maintenance time will be delayed to a certain extent. The technological requirements of specific equipment are generally strict. The manufacturer can only get them from foreign manufacturers. These are unique devices that are applied to specific areas. Moreover, people in the industry all know it. Therefore, the delivery time will be deliberately extended, seriously affecting the ship maintenance time.

The enhancement project for maintenance refers that the actual maintenance is more than the regular maintenance, such as we change it from dock maintenance to minor maintenance according to the real situation. The reason why this situation exists is determined by the increase in the actual use of ships. In the past, most of China's ships were patrolling along the coast, and most of the time they were parked on the shore. As China's "going out" strategy is put forward, more ships are going to distant waters to perform tasks, such as patrol in the South China Sea and escort in the Gulf of Aden. With the change of mission location and mission time, not only the working time of equipment but also the corrosion of ships in the environment of high temperature, high salt, and high humidity are increased.

III. Simulation Model Construction

The structure of this model to predict maintenance time based on Arena is shown as follows (major maintenance is not considered):

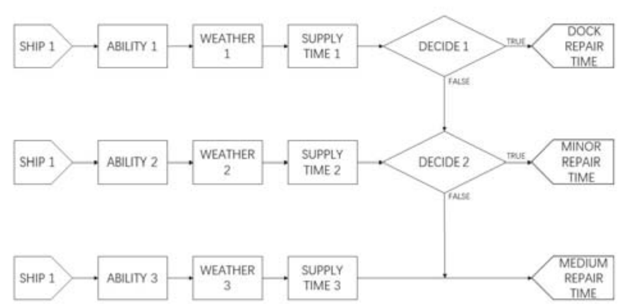

Fig.2 Structure of the model

Some icons are used in this model.

The rectangle with a triangle on the right is the arrival of the event. According to the type of event arrival, it can be separated into exponential arrival, scheduled arrival, and continuous interval arrival. According to the arrival type and historical data, the corresponding parameters can be determined to define the arrival situation of the event.

The rectangle is the influencing process. In this paper, each influence factor is set as an influence process, and its distribution is determined according to historical data and empirical data.

The diamond is a judgement. It refers to the impact of the enhancement projects on maintenance time. When there is no enhancement projects, the judgment is true and the maintenance time continues being solved. When there is an enhancement project, the judgment is false, and it moves to a more intricate maintenance process. In this paper, the probability of the existence of the enhancement project is expressed by setting the proportion.

The rectangle with a triangle on the left represents the end of the whole process and outputs pertinent data of maintenance time.

IV. Quantitative Analysis of Model Parameters

We now discuss the arrival process of the ship, the weather and the probability of the enhancement project and then analyze the impact of different data on maintenance time. For business confidential, the real data is not available, so artificial data are used.

A. The arrival process of the ship

Let the distribution of the weather, the abilities for maintenance and the supply time be precisely the same in all three repair modes. The decision process is true and the maintenance time continues being solved; that is, there is no enhancement projects.

Suppose the dock maintenance follows a Poisson distribution with parameter 1, the minor maintenance with parameter 2, and the medium maintenance with parameter 5. After running the system for ten times, the maintenance time of the three maintenance modes is shown as follows.

TAB.1 Poisson distribution of arrival process

Maintenance Types	Arrival Process	Maintenance Time
dock maintenance	Poisson distribution with parameter 1	2.4590
minor maintenance	Poisson distribution with parameter 2	2.5154
medium maintenance	Poisson distribution with parameter 5	2.4493

By observing the table above, we find that the maintenance time is the same. In other word, the arrival process of the ship does not affect the maintenance time. To verify this result, we set different arrival distributions for the arrival process, and the distributions and results are as follows.

TAB.2 Constant distribution of arrival process

Maintenance Types	Arrival Process	Maintenance Time
dock maintenance	constant distribution with parameter 1	2.4913
minor maintenance	constant distribution with parameter 2	2.5449
medium maintenance	constant distribution with parameter 5	2.6598

Judging from the above results, the arrival process of the ship does not influence on the maintenance time. There will be no constraint on the arrival process when additional factors are discussed later. We set the docking repair to follow a Poisson distribution with parameter 1, the minor maintenance with parameter 2, and the medium maintenance with parameter 5.

B. The weather during a maintenance process

Since the weather, the abilities for maintenance and the supply time are all influence processes, and their forms are the same, only one is discussed. Here we take the weather as an example.

Let the distribution of the abilities for maintenance and the supply time for maintenance under the three maintenance modes be the same ones. And there is no enhancement projects.

Consider the weather alone. Assuming that dock maintenance follows a normal distribution with parameter (1,0.5), minor maintenance with parameter (2,1), and medium maintenance with parameter (5,2.5). After running the system for ten times, the maintenance time of the three maintenance modes is shown as follows.

TAB.3 Normal distribution of the weather

Maintenance Types	Weather	Maintenance Time
dock maintenance	normal distribution with parameter (1,0.5)	2.4313
minor maintenance	normal distribution with parameter (2,1)	3.5241
medium maintenance	normal distribution with parameter (5,2.5)	6.1030

Change the distribution type of the weather. Assuming that dock maintenance follows a uniform distribution with parameter (0,1), minor maintenance with parameter (0,2), and medium maintenance with parameter (0,5). After running the system for ten times, the maintenance time of the three maintenance modes is shown as follows.

TAB.4 Uniform distribution of the weather

Maintenance Types	Weather	Maintenance Time
dock maintenance	uniform distribution with parameter (0,2)	2.5262
minor maintenance	uniform distribution with parameter (0,4)	3.3756
medium maintenance	uniform distribution with parameter (0,10)	6.8122

Change the distribution type of the weather again. Assuming that dock maintenance follows a triangular distribution with parameter (0,1,2), minor maintenance with parameter (0,2,4), and medium maintenance with parameter (0,5,10). After running the system for ten times, the maintenance time of the three maintenance modes is shown as follows.

TAB.5 TRIANGULAR DISTRIBUTION OF THE WEATHER

Maintenance Types	Weather	Maintenance Time
dock maintenance	triangular distribution with parameter (0,1,2)	2.4944
minor maintenance	triangular distribution with parameter (0,2,4)	3.4678
medium maintenance	triangular distribution with parameter (0,5,10)	6.4469

Observing the above operation results, we found that the weather has a significant impact on the maintenance time. When severe weather lasts for an average day, maintenance time increases by one day. It is consistent with the actual situation. When bad weather occurs, maintenance workers are unable to carry out their work and can only continue after it.

C. The enhancement project

Let the distribution of the weather, the abilities for maintenance and the supply time in the three maintenance models be the same, namely the weather follows a normal distribution with parameter (1,0.5), the abilities for maintenance follows a uniform distribution with parameter (0,1), and the supply time follows a triangular distribution with parameter (0,1,2). Under the three maintenance modes, the probability of an enhancement project exists is 0.7, 0.4 and 0. In other words, the decision-making process of 30%, 60%, and 100% is true. After running the system for ten times, the maintenance time of the three maintenance modes is shown as follows.

TAB.6 PROBABILITY OF AN ENHANCEMENT PROJECT

Maintenance Types	Enhancement Project	Maintenance Time
dock maintenance	30% for true	2.4758
minor maintenance	60% for true	2.4910
medium maintenance	100% for true	2.5495

As can be seen from the above table, the existence of the enhancement project has little impact on the maintenance time. The only difference is that the maintenance level has been improved and more resources are needed. It may influence the maintenance plan and resource arrangement to some extent.

V. CONCLUSION

Based on Arena, this paper establishes a prediction model and realizes the prediction of ship maintenance time. The weather, the abilities for maintenance, and the supply time have important impact on maintenance time while the arrival process and the enhancement project have little. The prediction results are of specific reference significance for management departments to arrange maintenance plans. Due to insufficient data type and data volume, the predicted results can only roughly reflect the influence of various factors on the predicted time. We can conduct further research from the following aspects. On the one hand, the collection of data types should be increased, including the operation and maintenance of various equipment on the ship; on the other hand, the accumulation of data should be strengthened to eliminate the prediction impact caused by inaccurate or incomplete data.

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