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Research on the Architecture of Radar Equipment Health Management System Based on Big Data

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Abstract: With the continuous improvement of radar performance and the increasing complexity, various information collection technologies and intelligent control technologies have been widely applied, and the reliability, fault diagnosis and prediction, as well as maintenance support of the entire radar system are receiving increasing attention. This article starts from the research on modern radar PHM requirements, and based on the application of big data in radar health management, proposes a radar equipment health management system architecture scheme based on big data. Finally, the relevant key technologies are analyzed.

Keywords: big data; Health management; Architecture

1. Introduction

With the continuous improvement of radar performance and the increasing complexity, various information collection technologies and intelligent control technologies have been widely applied. The reliability, fault diagnosis and prediction, as well as maintenance support of the entire radar system, are receiving increasing attention. Prognostics and Health Management (PHM) is a further expansion of traditional monitoring capabilities, and the main technical element of this development is the transition from status monitoring to health management. This transformation introduces intelligent diagnosis and prediction capabilities, which can identify and manage the occurrence of faults, plan maintenance, and supply support, making it a comprehensive fault detection, isolation, and prediction technology. This technology is not aimed at directly eliminating faults, but rather at understanding and predicting when faults may occur, or triggering a simple maintenance activity when unexpected faults occur, in order to achieve self-service support and reduce usage and support costs[1-3]. Health management technology maximizes the use of traditional fault feature detection technology, utilizing advanced sensors and various algorithms and intelligent models to monitor, manage, and predict the operational status of radar, thereby obtaining accurate fault detection and isolation results.

The rapid development of big data and cloud computing technology, as well as the popularization of high-speed broadband networks, have made the idea of building a distributed and shared fault prediction and health management platform based on cloud services a reality. The Internet of Things, cloud logistics, and RF technology have

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made it possible for radar equipment and equipment to be "intelligent". Maintenance equipment identification, positioning, tracking, and monitoring have been automated, and on-demand application and distribution have greatly improved the efficiency and level of radar equipment maintenance. Cloud manufacturing services can integrate manufacturing resources and use 3D printing technology to accurately simulate equipment damage models. New technology will inevitably give birth to new guarantee modes, which determine the new system architecture and provide new service modes[4-5].

2. Analysis of Research Status

2.1. Current Research Status Abroad

Since the late 1990s, with the rapid development and widespread application of information technology, integrated diagnostic systems have developed towards the integration of testing, monitoring, diagnosis, prediction, and maintenance management. The time has come to form an integrated diagnosis, prediction, and health management system. In this situation, the US military has introduced condition based maintenance (CBM) as a strategic equipment support strategy, Its purpose is to monitor the status of equipment in real-time or near real-time, and determine the optimal maintenance time based on the actual status of equipment, in order to improve the availability and task reliability of equipment.

The basic idea of health management originated from health detection and was first applied in the engine monitoring of A-7E aircraft in the United States in the mid-1970s. It went from Integrated Vehicle Health Management (IVHM) to Integrated System Health Management (ISHM), and then to the emergence and application of theories and system technologies such as Fault Prediction and Health Management (PHM), The health management technology of complex systems is constantly developing, and in recent years, its functions have evolved from risk monitoring and fault prevention to precise risk control, risk decision-making, and integrated optimization[6-8]. For example, the Enhanced Condition Based Maintenance (CBM+) proposed by the US Department of Defense, and the Technologies and Technics/Ques for New Maintenance Concepts (TATEM) completed by 12 European countries have put forward higher requirements for reliability assessment and life prediction techniques in complex system health management.

In terms of the implementation effect of health management technology, the US Department of Defense F-35 Joint Strike Fighter (JSF) project is the most significant. Health management is a key to achieve the economic, supportability and Survivability goals of JSF project. JSF's health management system is a development of BIT (Build In Test) and status monitoring currently used on aircraft. The main technical element of this development is the transition from status health monitoring to status health management, which introduces fault prediction ability to identify and manage the occurrence of faults. After adopting health management technology, the non recurrence rate of F-35 aircraft faults has been reduced by 82%, maintenance manpower has been reduced by 20% to 40%, logistics scale has been reduced by 50%, and the number of flights has been increased by 25%. The use and support costs of the aircraft have been reduced by more than 50% compared to previous models, and the service life has reached 8000 flight hours. Statistical data fully demonstrates the important role of health management in reducing maintenance support costs, improving the safety, availability, and completeness of weapons and equipment, ensuring mission success, and enhancing combat effectiveness[9-10][16-18].

2.2. Domestic Research Status

In terms of equipment health management system engineering application in China, it has far lagged behind the advanced level of developed countries abroad. Currently, health management technology has not yet been fully transformed into engineering applications. In the aviation field, focusing on model technology research, testability design and verification, diagnosis and performance degradation prediction technology research and related verifications have been carried out for flight control systems, rotary drive devices, hydraulic energy systems, accessory casings, power supply systems, avionics processors, metal/composite body structures, etc. In the field of aerospace, currently, satellite power systems mainly carry out in orbit state monitoring, performance degradation prediction, operation management, and life extension of solar arrays, batteries, and controllers; Manned spaceflight has also carried out state monitoring and fault tolerant control for some key systems[1-2]. In the field of shipbuilding, technology applications such as condition monitoring, fault diagnosis, operation and auxiliary maintenance decision-making are mainly carried out for key equipment of the main and auxiliary engine systems (diesel engines, pump equipment, variable pitch propeller devices, ship surface systems, etc.). In the field of weapons, on-board condition monitoring and auxiliary maintenance guidance, enhanced diagnosis of monitoring centers, task and maintenance assistance, and decision-making engineering applications have been carried out for launch vehicles in a network environment.

3. Analysis of Health Management System Architecture Based on Big Data

With the continuous improvement of the performance of large-scale weapon systems and the increasing complexity of their composition, the problems exposed in reliability, fault diagnosis, maintenance support, and other aspects are also becoming increasingly prominent. The traditional maintenance mode is difficult to avoid "over maintenance" and "under maintenance". Therefore, the condition based maintenance (CBM) mode has received attention and application, and has also promoted the research and development of fault prediction and health management (PHM) technology. By improving maintenance support capabilities, the integrity and availability level of equipment can be ensured, enabling new equipment to form combat effectiveness as soon as possible.

3.1. Big Data Analysis

Currently, more and more radar information and data are being reported to remote control centers. The maintenance and support mode of radar equipment has shifted from on-site personnel support to networked remote intelligent support. How to effectively utilize these big data for remote intelligent fault diagnosis and health assessment of radar is a new challenge faced by the radar comprehensive support profession. The massive feature data generated during the operation of radar systems contains a large amount of fault information. How to extract fault information from the big data of complex equipment operation characteristics and achieve rapid diagnosis of operation faults is of great significance for improving the safety of complex equipment and achieving stable operation[11-13].

Modern radar requires the implementation of full life cycle management for equipment, and health management systems must have the processing ability of massive data and the deep mining function of big data. They can use advanced algorithms to establish corresponding models, predict the operating trends of radar systems or components, and make decisions for maintenance support. Through the organic combination of big data technology and health management systems, radar can have the intelligent perception ability of battlefield environment, and have the functions of online intelligent decision-making and offline autonomous learning; It can effectively integrate the data resources of radar in service, connect design, production, after-sales and other life cycle stages together, and truly achieve full life cycle management of radar equipment.

3.2. Design of Modern Radar PHM Architecture

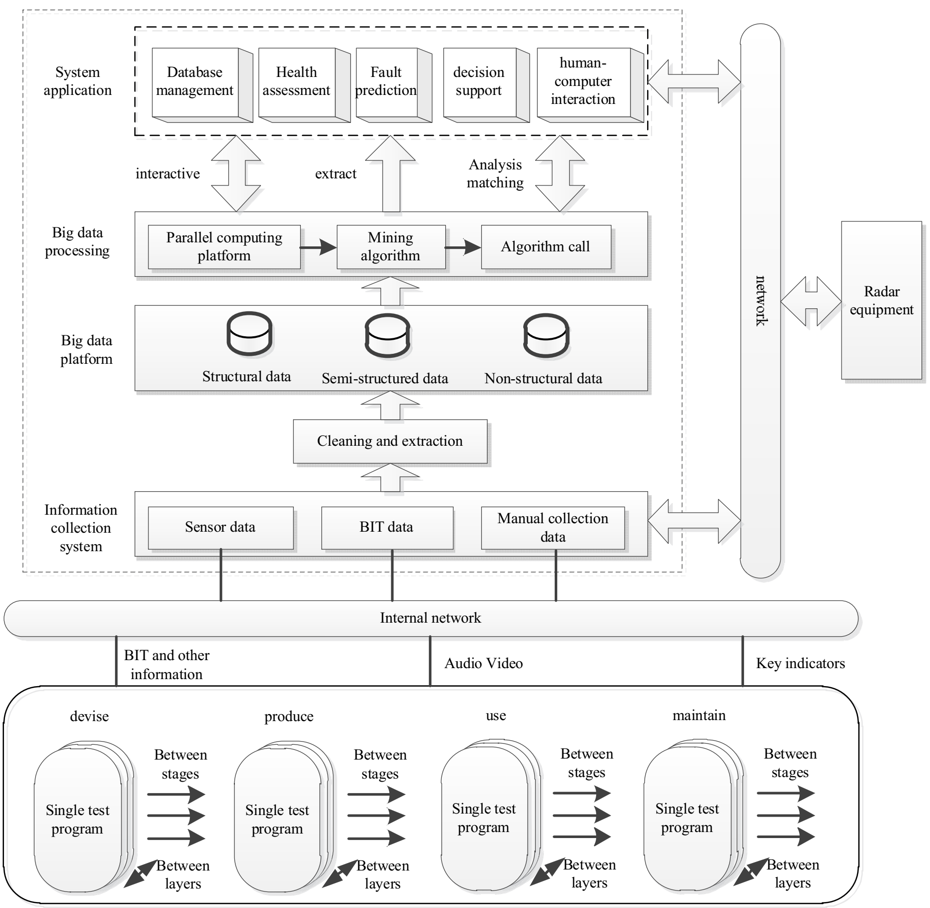

Figure 1. Architecture of Modern Radar PHM System Based on Big Data

At present, the internationally recognized health management system architecture is OSA-CBM (Open Architecture for Condition Based Maintenance), which integrates the common design ideas, application technologies, and methods of health management systems in different fields. It has been preliminarily applied and validated in many systems, including US Navy ship systems, aircraft, civilian vehicles, and other industrial fields, and has become a widely followed system framework in the industry. Based on the OSA-CBM architecture, this article designs a radar system PHM overall architecture based on big data, which mainly includes several parts such as status processing monitoring, health status assessment, fault status prediction, maintenance and repair strategies, database and management, and human-machine interaction. The specific PHM architecture is shown in Figure 1.

(1) Data collection: This section utilizes various sensors to collect relevant parameter information of the system, providing the data foundation for the health management system, and also has functions such as data conversion and transmission.

(2) Data processing: This section receives signals and data from sensors and other data processing modules, and processes the data into the format required for subsequent processing of parts such as status monitoring, health assessment, and fault prediction. The output results of this section include filtered, compressed and simplified sensor data, spectral data, and other feature data.

(3) Status monitoring: This section receives data from sensors, data processing, and other status monitoring modules. Its main function is to compare these data with predetermined failure criteria, etc., to monitor the current state of the system. And it can provide fault alarm capability based on predetermined limit values/thresholds of various parameter indicators.

(4) Health evaluation: This section accepts data from different status monitoring modules and other health assessment modules. The main assessment is the health status of the monitored system (which can also be subsystems, components, etc.) (such as whether there is parameter degradation phenomenon, etc.), which can generate fault diagnosis records and determine the possibility of fault occurrence. Fault diagnosis should be based on various health status historical data, working status, and maintenance historical data.

(5) Predictive evaluation: This section can comprehensively utilize the data information of the aforementioned parts to evaluate and predict the future health status of the monitored system, including remaining lifespan. Fault prediction ability is one of the significant characteristics of health management systems.

(6) Decision suggestion: This section accepts data from the status monitoring, health assessment, and fault prediction sections. Its main function is to generate recommended measures such as replacement and maintenance activities. Maintenance measures can be taken at an appropriate time before the monitored system malfunctions. This section implements the ability to manage health management systems, which is another significant feature.

(7) Data management: The main function of this section is to record raw feature parameter data, historical fault data, and databases that may be required by the health management system, such as a health management system that uses expert systems as inference algorithms. Data management also includes its knowledge base.

(8) Information interface: This section mainly includes human machine interface and machine machine interface. The human-machine interface includes the display of warning information in the status monitoring module, as well as the representation of data information in the health assessment, prediction, and decision support modules;

The machine machine interface enables the transmission of data information between the aforementioned modules and between the health management system and other systems (such as automated operation).

4. Key Technology Analysis

(1) Status monitoring and health management technology. Require the use of advanced sensors to obtain as accurate as possible information on the operational status of electronic systems, and obtain accurate estimates of the health status of electronic systems by designing more advanced data analysis techniques.

(2) Diagnostic techniques. It is very important to locate faulty modules or components during system maintenance. Due to the insufficient degree of failure at this point to completely disable the system, most of them belong to early fault states. Therefore, designing advanced feature extraction techniques and classifiers with good performance is particularly important.

(3) Predictive technology. When a system, subsystem, or component may experience small defects or early failures, or gradually degrade to a point where it cannot perform its function at its best, relevant detection methods are selected and predictive systems are designed to detect these small defects, early failures, or degradation, in order to prevent them from occurring before they occur. It is generally divided into two categories: system state prediction and life prediction.

(4) Information fusion technology. Multi sensor data fusion refers to the intelligent processing of sensor arrays composed of two or more sensors that have collaborative, complementary, and competitive properties. Its purpose is to integrate their respective information with the highest efficiency diagnostic method, in order to obtain more accurate conclusions for determining the state of electronic systems.

(5) Artificial intelligence technology. Artificial intelligence technology is widely used in PHM, including expert systems (model-based reasoning, case-based reasoning, rule-based reasoning), neural networks, fuzzy logic, and genetic algorithms. Through their intelligent reasoning, accurate monitoring of system status and fault diagnosis can be achieved[14-15].

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