Discussion on Application of Big Data Technology in Weapon Equipment PHM

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Abstract—Prognostics and health management (PHM)techno-logy, as a key technology to realize new ideas and new schemes such as condition-based maintenance (CBM), autonomous support (AL), perception and response logistics, is an important dual-use technology to improve the general quality characteristics of complex systems and reduce life cycle costs. Big data technology refers to the application technology of big data, covering various big data platforms, big data index systems and other big data application technologies. Big data technology has brought new ideas and methods to the deep application of weapon equipment prognostics and health management (PHM). This paper analyzes the current situation and characteristics of weapon equipment PHM big data, proposes the application framework of weapon equipment PHM big data technology, and discusses the technical approaches and application ideas to support the improving the combat effectiveness of weapon equipment.

Keywords - Weapon equipment; Big data; Prognostics and health management; Data processing; Model algorithm

1 INTRODUCTION

With the continuous advancement of weapon and equipment informatization, new sensors and information systems for equipment design, testing, production, use and maintenance of various aspects of monitoring records to promote the formation of weapon and equipment big data[1], these big data for the application of weapon and equipment failure prediction and health management provides a more fertile "soil". At the same time, big data storage and analysis, the improvement of computer computing power and the breakthrough of deep learning algorithms have greatly promoted the application of big data and artificial intelligence technology in civil scenarios such as the Internet, finance, unmanned vehicles, and intelligent medical care, etc. Many countries have also placed big data technology at the level of national strategy to promote it, making it a strategic high point to seize technological advantages in the new century and a major technological development direction in the coming years. technology development

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direction, Big Data technology is impacting the established trajectory of the world's development in an unprecedented way.[2]

PHM technology, as a core technology in Industry 4.0, has received increasing attention and application from military powers such as the US and UK, and has become a requirement for weapons systems procured by the US Department of Defense [3]. PHM technology has been applied abroad in civil aviation, automobiles, roads and bridges, nuclear power plants, large dams and other civil fields, making it a veritable dual-use technology in the 21st century [4]. In China, PHM technology research and application has been carried out mainly in the aviation, aerospace, railway and automotive industries [5][6][7][8], but in recent years, it has been difficult to adapt PHM to the high-speed and variable use environment of weapons and equipment due to its system-level data integration, data processing capability and the accuracy of fault diagnosis and prediction, resulting in the limited in-depth application of PHM systems in weapons and equipment, and big data technology The development of big data technology has provided the technology and foundation to solve these problems, making PHM one of the important application scenarios of big data and artificial intelligence on the battlefield.

On the basis of the current situation and characteristics of big data of weapons and equipment, this paper establishes a framework for the application of big data technology in PHM of weapons and equipment, and gives the key technologies and application ideas to realize the application framework, in order to provide a solution for the application of big data technology in fault prediction and health management of weapons and equipment.

2 WEAPONRY PHM BIG DATA

The complex composition of weapons and equipment, the high speed and variability of the use environment coupled with the uncertainty of failure occurrence, lead to the difficulty and low accuracy of equipment failure prediction and health management. In the life cycle of weapons and equipment, the equipment itself and the periphery produce a large amount of data, which provides rich raw materials for analysis and decision making. These data are directly or indirectly recorded with information related to the health status of the equipment, which provides support for the PHM of weapons and equipment from different perspectives and has become an important basis for fault diagnosis and prediction. Therefore, in order to comprehensively assess and predict the health status of the equipment, the scope of PHM big data for weapons and equipment includes the equipment itself and peripheral data.

2.1 Weaponry PHM Big Data Status

Weapons and equipment information technology, automation level and the interpenetration and integration with the Internet of Things, so that equipment design and production enterprises and the use of the internal sector has accumulated a large amount of data, for a particular equipment, mainly including design data, production data, operational data, environmental data, and equipment failure maintenance guarantee data, etc., belonging to different units and personnel, equipment PHM big data generation framework as shown in Figure 1.

Weapons and equipment PHM big data is generated with the stages of the whole life cycle of weapons and equipment, with a strong chronological relationship, and some of the data are correlated with each other. At the same time, the PHM big data of weapons and equipment also has problems such as poor co-ordination and planning, and low utilization of data value. The reason for these problems is that on the one hand, the shallow data mining algorithm cannot meet the actual use requirements, and on the other hand, it is because the traditional database technology has gradually failed to meet the needs of information system integration, while the big data technology has the ability to break through the traditional technical limitations, which has laid the technical foundation for solving the problems of PHM big data of weapons and equipment in terms of collection, storage and value mining.

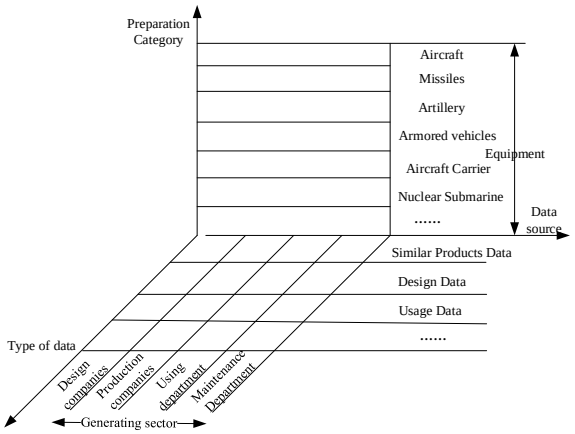

Figure 1. Equipment PHM big data generation framework

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2.2 Big data characteristics of weaponry PHM

Weaponry PHM big data has four typical characteristics of big data, such as Volume, Variety, Velocity, and low value density, etc. It is manifested as a larger amount of data, not fragmented data samples, but the whole data; data structure is more mixed, and the amount of unstructured data is proliferating, accounting for an increasing proportion; data The relationship between the data is more complex and difficult to mine, especially the deep-level correlation [9]. And in

addition to the 4V characteristics of weaponry PHM big data, the following characteristics also exist at this stage.

1) High dimensionality. A variety of complex physical and chemical changes occur during the operation of weapons and equipment, equipment internal, equipment and environment, equipment and equipment, equipment and target between the interaction, the dimensionality of data variables increased sharply, which makes access to the internal and peripheral state of weapons and equipment become complex and variable. And with the rapid development and in-depth application of cloud computing, multimedia and mobile computing, the data variables of weapons and equipment and their dimensions will also grow rapidly.

2) Noise complexity. It is mainly reflected in two aspects: firstly, there are many kinds of noise, weapons and equipment are affected by complex environment, and there are interactions between different environmental factors, such as vibration and impact stress will promote or offset each other; secondly, it is noisy, because it is difficult to shield weapons and equipment from the influence of harsh environment during operation, especially land-based equipment is more prominent, PHM data will be inevitably generated in the process of collecting noise.

3) Weakness of system. Weapons and equipment enterprises and using departments have experienced 20 years of information construction, forming a large number and variety of information application systems, but the information application systems are relatively independent of each other, thus forming information islands. One reason is the lack of data integration technology between information systems; on the other hand, the weapons and equipment industry has a high degree of confidentiality, increasing the difficulty of sharing data at different stages of equipment and making it difficult to form an equipment information chain.

3 APPLICATION FRAMEWORK OF BIG DATA IN WEAPON EQUIPMENT PHM

Combined with the current situation and characteristics of PHM big data, the application framework of big data technology of weapon equipment PHM is designed by using the hierarchical system design idea, as shown in Figure 2.

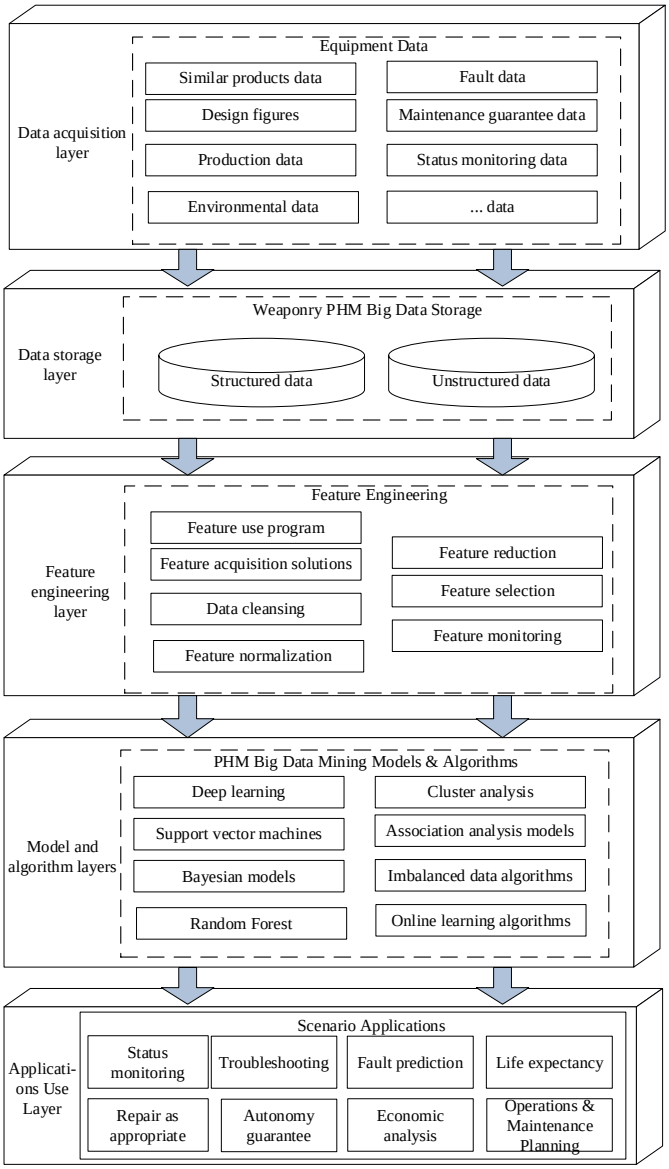

Figure 2. Framework for the application of big data technology in PHM

As can be seen from Figure 2, the main function of the data acquisition layer is to import the status monitoring signals collected by various sensors in the operation of weapons and equipment into the terminal and upload them to the server, and design the data interface to upload the equipment's resume data and similar product data to the server, including structured data and unstructured data. The data collected by sensors are in various formats, and it is difficult to integrate data between different information systems. The data storage layer should have the ability to store structured and unstructured data. Before mining and learning big data,

feature engineering should be carried out to remove noise, outliers and standardize the data. Then, the data is transferred to various algorithms in the model and algorithm layer to establish the mapping relationship between sensor signal data and the health status of weapons and equipment. The large data set of weapons and equipment has the characteristics of fewer negative samples and cruel and changeable service environment. The unbalanced data algorithm and association analysis model are mainly developed. Finally, the analysis results of the model and algorithm are applied to PHM system in the application layer, interactive and visual display.

4 KEY TECHNOLOGIES

4.1 Weapon equipment PHM big data storage based on Hadoop

The PHM big data of weapon equipment includes structured data and unstructured data, which are independent of each other and the amount of data is increasing with the passage of time. It is very necessary to build a multi-source, multi-level and easily extensible data storage platform to realize the centralized storage of PHM big data of weapon equipment. Most traditional of large-scale data processing using distributed high performance computing and grid computing technology, requires expensive computing resources, but also for how to large-scale data effective segmentation and reasonable distribution of computing tasks require tedious programming to achieve, and the development of the Hadoop distributed technology can solve the above problems, The big data storage architecture of weapon equipment PHM based on Hadoop is shown in Figure 3.

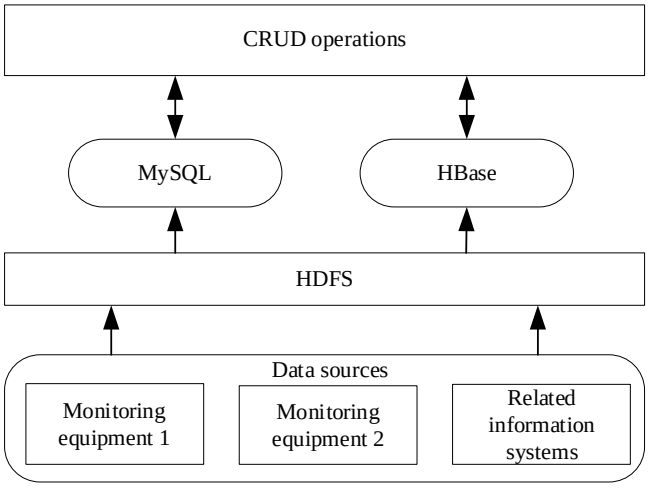

Figure 3. Hadoop-based PHM big data storage architecture

During the normal operation of weapons and equipment, there are a variety of monitoring equipment for the condition monitoring of key components of weapons and equipment, such as vibration sensors, current sensors, temperature sensors, oil sensors, performance monitoring,

etc. The information systems related to PHM also record the biographical data of equipment and play an important role in the health management of equipment, such as design information system, process information system, assembly information system, etc. The data collected by multiple monitoring devices and related information systems are stored in the HDFS. On the upper layer of the HDFS, the relational database MySQL and non-relational database HBase are used to call and read data to provide input for subsequent data processing. Users can perform CRUD operations on the database.

4.2 Big data processing of weapon equipment PHM based on Spark

Spark is an efficient distributed computing system based on memory computing [11], which is suitable for the application scenarios with large amount of computing and high efficiency requirements. Internet enterprises such as Baidu, Taobao, Tencent, JD.com, Youku Tudou, and Yahoo all adopt Spark technology. The big data processing architecture of weapon equipment PHM is shown in Figure 5.

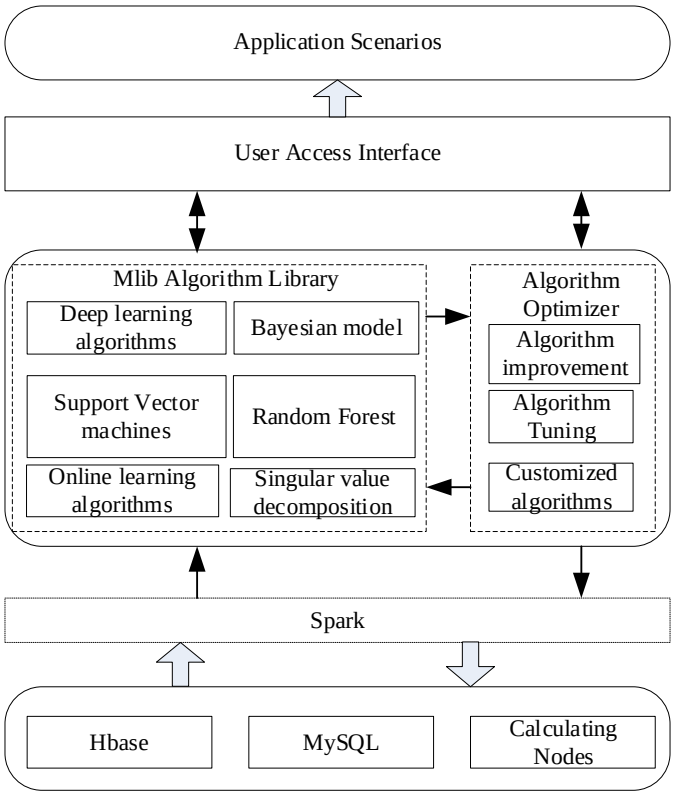

Figure 4. Big Data processing architecture based on Spark

Spark first reads data from MySQL database and HBase, converts the data format to the data format that can be invoked by MLlib algorithm library [12], and then calls the algorithm in MLlib to train the data. For real-time monitoring and evaluation of PHM, the Spark component reads real-time data, which is the running data of the equipment. The real-time data is mixed

with the original data, and the best model is used to perform real-time evaluation of the equipment. In order to improve the performance of the algorithm, the algorithm optimizer is set up to provide methods such as parameter tuning, algorithm improvement, and custom algorithm. As a computing framework, Spark has an interface with users to accept machine learning tasks and return learning results to users.

4.3 PHM big data mining model and algorithm design

Model and algorithm are indispensable tools for big data analysis and processing of weapon equipment PHM. The analysis results of model and algorithm are directly presented to users. The performance of algorithm determines whether big data technology can be successfully applied in weapon equipment PHM. In the process of PHM big data analysis and processing of weapons and equipment, there are both supervised learning and unsupervised learning, and there are both classification and regression problems. The algorithm is improved according to the characteristics of equipment data. In the design and selection of high performance algorithms, on the one hand, the parameters of the algorithm are tuned, and on the other hand, the integration of algorithms is emphasized, such as the combination of random forest and neural network, gradient lifting decision tree and logistic regression, etc. The model and algorithm design flow are shown in Figure 6.

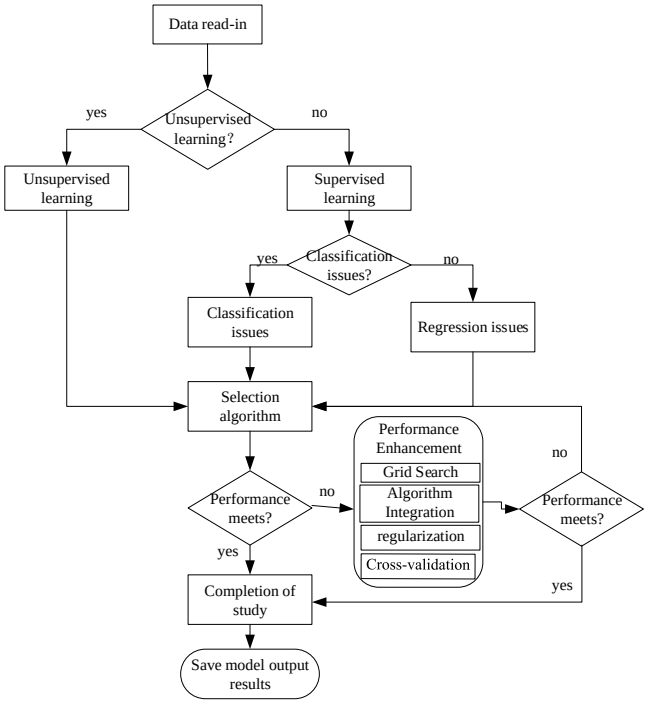

Figure 5. Flow chart of model and algorithm design

5 IDEA OF APPLICATION

As the main weapon system platform based on land, the ability of fault diagnosis and prediction of armored vehicle in use is of great significance to give full play to its efficiency. In the process of design, production, use and maintenance of armored vehicles, a large amount of data will be generated. The establishment of correlation between these data and fusion analysis will provide important support for improving the accuracy and efficiency of weapon equipment PHM system.

The PHM system of armored vehicles is used for big data application. The system design is shown in Figure 7.

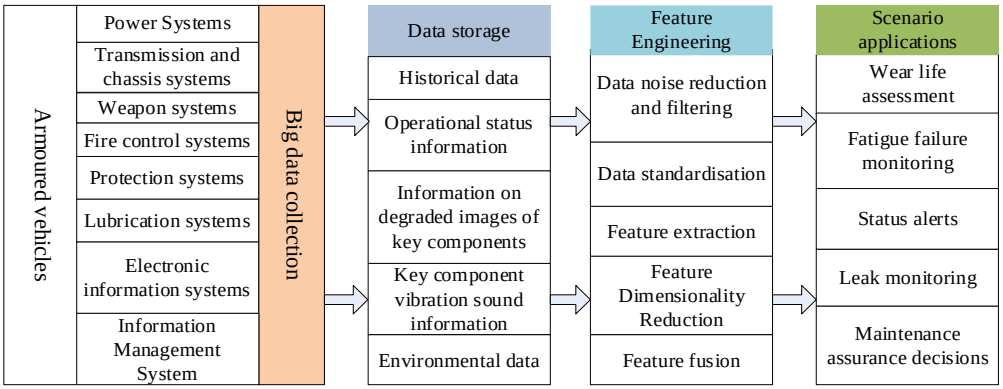

Figure 6. Scenario of the application of the PHM big data system for armament vehicles

Fatigue, wear, breakage and leakage are the main faults of armored vehicles, which are mostly degenerative faults. The system collects and monitors the related similar product data, environmental data, operating image and sound state data, so as to improve the diagnosis and prediction ability of typical faults of armored vehicles. The system functions include big data collection, data storage, feature engineering, model and algorithm, and scenario application. Through different sensors and information systems, the big data acquisition obtains multi-directional operating status data of armored vehicles, image and sound data of degradation of key components, historical data, etc., as the input of armored vehicle PHM. Data storage provides an open storage environment for the collected PHM big data. The feature engineering is responsible for data preprocessing and feature extraction. The armored vehicle runs on the harsh ground environment, and vibration is the main environmental stress of the armored vehicle. In the application of the scene, the difficulty is to support the application of various scenarios algorithm, according to the characteristics of the scenes demand and collect data development calls the background and the adaptive algorithm, on-line monitoring sensors to monitor the key parts such as degradation phenomenon, contain the information such as image, voice, and stored in the form of sequence according to time, it puts forward high requirements on big data mining, Deep learning and time series integration algorithms need to be introduced, such as the integration of high-precision neural network learning models such as CNN, ResNet, DenseNet and time series algorithms. High-precision algorithms are also crucial to accurate maintenance support decisions and improve equipment efficiency.

6 CONCLUSION

As a key technology to realize new ideas and schemes such as weapon equipment`s condition-based maintenance (CBM), autonomous logistic (AL), sensing and response logistics, PHM is an essential military-civil application technology to improve the general quality characteristics and reduce the life cycle costs of complex systems. Big data and artificial intelligence are the future development direction of battlefield. PHM technology combined with big data and artificial intelligence technology is one of the most important application scenarios of big data and artificial intelligence on the battlefield. This paper analyzes the weapon equipment PHM`s big data characteristics and mainly discusses the application framework and key technologies of the weapon equipment PHM technology. Taking the development of big data technology as an opportunity to promote PHM technology`s deep application in the weapon equipment field, the proposed framework will provide reference for the application of the weapon equipment PHM technology in relevant departments, scientific research and production enterprise.

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