A design concept of flight test database system based on WBE technology

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ABSTRACT

The current design concepts and systems of aircraft have developed exceptionally complex and precise,various newly developed or improved aircraft models need to undergo several years of rigorous flight test validation before being put into practical application. Therefore, a large number of flight test data are generated during the flight test. Effectively managing and analyzing the data obtained during flight tests to ensure safety is the key to the entire flight test. Based on the C/S architecture of web technology, an attempt is made to establish a flight test database system, which is divided into client software and service support subsystems. Using C/S structure can not only enhance the security of the system, but also provide users with a powerful system management interface and rich database management means, which makes the maintenance of the system more simple and reliable. To improve the query efficiency of the database, Spark tool is used to establish query connections for multi-channel spatial datasets using iterative methods. The system test results show that the actual rate of file upload and download can reach 60 -70Mb/s per second, which can meet the performance requirements of flight test organization for file upload and download. This database can provide reference for flight test units and civil aviation enterprises, providing strong technical support for flight test safety and civil aviation safety.

Keywords: WBE technology; flight test; flight test safety; database system

1. INTRODUCTION

The onboard data acquisition and processing system requires that the collected data files can be used immediately after the test flight, and relevant data can be randomly selected for analysis to evaluate the effectiveness of the test flight subjects or locate aircraft faults. Xu Yingkang et al. utilized the concepts and theories of modern computer and network application technology, as well as hierarchical relational databases, to construct a flight test database system. Through the system, flight test data and various technical data generated during the flight test organization process were collected and managed, and a database management and application system for flight test data of corresponding experimental objects and related testing equipment was established for reference by relevant units [1]. Flight test data integrates multi-department, multi-source and multi-scale structured and unstructured data. These data have different types, changeable formats and huge volume, which makes researchers spend a lot of time in their daily work.

The configuration structure of modern aircraft is generally very complex, and various typical configuration combinations need to be verified by flight test before they are put into practical application [2-3]. Therefore, a large number of flight test data are generated during the flight test. In recent years, with the development of information technology, turning various types of data into database has become a powerful booster for countries all over the world to continue to develop and enhance their comprehensive competitiveness [4]. The advantage of object-oriented database is that it can represent complex data models, but because there is no unified data schema and formal theory, it lacks strict data logic foundation [5]. By combining with multidisciplinary technology, establishing a series of new databases, such as distributed databases, parallel databases, knowledge bases, and multimedia databases, will be an important development direction for database technology in the future [6]. At present, flight test related engineers are focused on their own data management and processing, and the data is often scattered. A large amount of data still relies on manual download and transmission, which is not only inefficient, but also unable to ensure the integrity, security, and consistency of data references. This will be a major bottleneck for the efficient development and flight testing of new aircraft models [7-8].

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How to ensure the safety of flight test, effectively manage and analyze the data obtained from flight test is the key to the whole flight test. The original decentralized manual flight test data management method has been difficult to meet the requirements, so it is necessary to develop an integrated comprehensive flight test database system. This system adopts the C/S structure based on WEB technology, which can not only ensure the flexibility of the system in development, but also meet the speed and breakpoint continuous transmission requirements of the system in the transmission of large files and multiple files, and is very suitable for the multi-node, multi-user and multi-role management status of flight test. At the same time, a multi channel spatial connection iterative query algorithm based on Spark is introduced, which preprocesses spatial data through grid partitioning and encoding, avoiding excessive data loading in memory at once, thereby accelerating query speed and providing fast data support for flight test safety.

2. RESEARCH METHOD

2.1 Structural design of flight test database system

The flight test database system is the general name of flight test database, test engineering database and their application systems based on network structure. Flight test has the characteristics of long cycle, wide specialty, great difficulty, complex engineering, high risk and huge cost, so it has become one of the biggest obstacles for many countries to establish aviation manufacturing. In order to meet the requirements of reliable storage, unified management, quick query and analysis, and quick visualization of flight test data of civil aircraft, a flight test database system based on big data is developed to realize centralized management, efficient access analysis and sharing of flight test data, and solve the problems existing in non-unified centralized management in data storage reliability, data access performance, data distribution and sharing efficiency, data access control, data comparison visualization and so on.

The structure of flight test database system adopts the design concept of software components, and the client software and service support terminal system are constructed by using unified components [9]. The two systems use unified user management, authority control, process control and other components to build a unified system framework. Figure 1 shows the structure of flight test database system. The entire system software is based on the C/S architecture of web technology, divided into two subsystems: client software and service support.

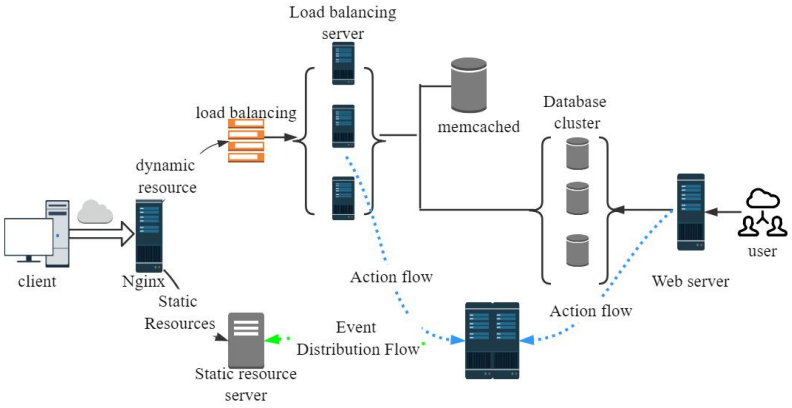

Figure 1. Schematic diagram of structural design of flight test database system

The database of the system includes one or more data tables, which contain multiple flight test data records, and each data record contains one or more flight test parameters. The flight test database system based on Web technology obtains the original data and analytical data stored in the original data storage file system and analytical data relational database through the original data access module and analytical data access module in the background. The platform has the ability to expand, and the platform can be expanded rapidly through configuration update to meet the requirements of more flight data entry and management.

It has been a long-term goal of enterprises to design and produce products with the highest scientific and technological level at the lowest cost in the shortest time. The development language is Java, which has good security, maintainability

and cross-platform characteristics [10]. Oracle is selected as the background database, which ensures the stability and performance of the system.。

The flight test database system needs to complete the following functions: project management, model management, configuration management, and other data organization functions; Special subject data management; Data query and analysis tools; And system management functions such as user management and data maintenance. The functional module organization of the flight test database system is shown in Figure 2.

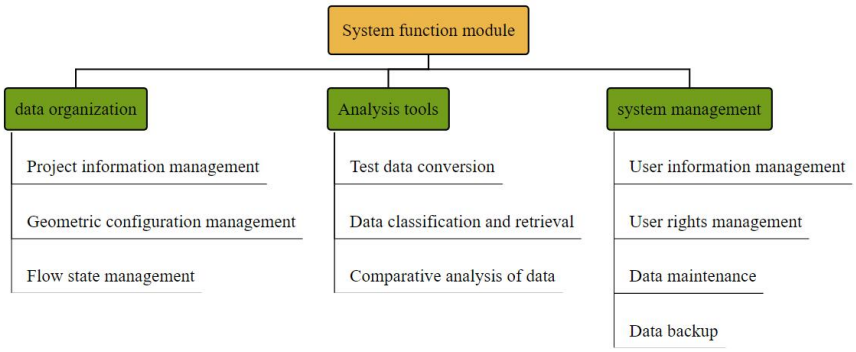

Figure 2. Functional module organization of flight test database system

2.2 Key technology realization

The amount of data collected during the flight test is large and stored in the form of files on the hard drive of the system server. The file header shows the state of the whole ground data acquisition and processing system, which includes the time information of data file acquisition, test number information, data storage information and network information; The index table is used to explain the position of the flight parameters used in the test in the data file, which includes the road number and the number of roads in the subframe or subframe where the parameters are located; The data block is the hard disk area where the data collected in the experiment is assembled. The network database server is the data center of the system, and users can obtain data information services according to the authorization of the system, or obtain specific data services through system operators. The database server also has certain computing power and provides certain computing services for users.

To ensure data quality, a quality monitoring platform is introduced, which implements quality measurement rules, checks and analyzes data quality, summarizes and forms quality problem reports, and provides a basis for quality improvement. Analysis of Quality Problems According to the requirements of quality improvement and the problems found in quality verification, a data governance analysis report and a quality improvement report are formed to provide a basis for data quality improvement.

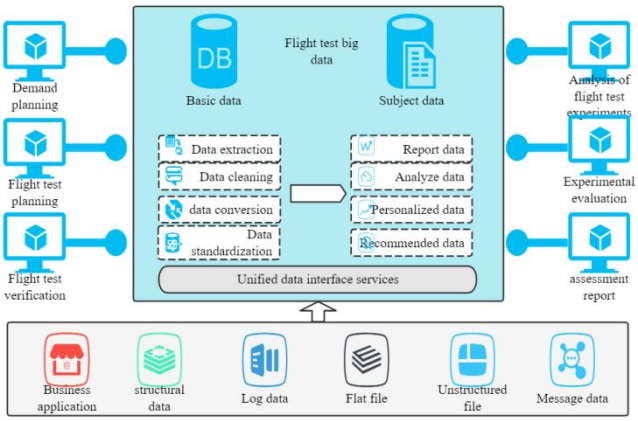

Figure 3. Flight test big data quality monitoring platform

Due to the large-scale of spatial warehouses and the complexity of dealing with them in practical applications, as show in fig.3, the sequential computing model in the traditional mode may finish the actual query task overtime. Spatial object relationship refers to the relationship between spatial objects with spatial characteristics. The relationships between spatial objects generally include blue categories: metric relationships, orientation relationships and topological relationships. Spatial join query is to retrieve all spatial objects that satisfy a spatial predicate (such as intersection and inclusion) from two data sets. Spatial objects are more complex and huge than words or strings that ordinary MapReduce applications deal with. Finally, the space division operation produces a large number of data copies, which makes it more difficult to build parallel space connection operations.

Spark is a parallel computing framework for big data based on memory computing. Spark abstracts each stage execution into a node in a directed acyclic graph, that is, the whole execution model is abstracted into a directed acyclic graph, and the tasks of multiple stages in the graph are executed in series or in parallel. To improve the query efficiency of the database, Spark tool is used to establish query connections for multi-channel spatial datasets using iterative methods. Using Z-order space filled curves for encoding can reduce the dimensionality of multidimensional spatial data, effectively alleviate the phenomenon of data skewing, and enable spatial data objects to be evenly distributed in corresponding partitions for processing, thereby improving overall performance [11].

The number of grids is related to whether the data can be evenly divided, whether the data in each grid can be completely loaded into memory and the replication rate of spatial data. The coding method and the mapping scheme of grid coding are to map the data in the grid to reducers, so that the amount of tasks obtained by each reducer can be kept as balanced as possible, thus improving the overall performance of the algorithm. The minimum number of grids can be calculated by Formula (1):

$$P = \left[\left(\|R\| + \|S\| \right) * (1 + p) * size_{kp} \right] / M \tag{1}$$

$\|R\|, \|S\|$ represents the sizes of two kinds of data sets participating in spatial connection calculation, and p is the replication rate of spatial data. M represents the memory size of each node, and $size_{kp}$ represents the size of a key element pointing to the actual data set.

In order to make full use of Spark's memory-based high-performance computing characteristics, this algorithm adopts Spark big data framework. The split operation is used to connect the two types of data sets, and the two types of data objects that do not overlap are filtered out. For the two types of data objects that do overlap, the partition unit that the data object of the second type crosses is calculated again through the split operation, and then each partition unit code obtained is used as the key value.

Put the MBR attribute information of these two data objects together as the value value and put it into the data structure. At the same time, considering Spark's high performance computing based on memory, the proposed algorithm is implemented with Spark. So as to improve the efficiency of connection query.

3. RESULT ANALYSIS

The performance test of the flight test database system based on big data is divided into two parts: the operational performance and stress test of the system and the time-consuming test of file upload/download transmission. We use JMeter tool to test the performance of flight test database system based on big data. JMeter is an open source Java-based stress testing tool. JMeter can not only test the white box of client software, but also test the stress and performance of server support subsystem. The performance test results show that the average response time is about 1 second, which fully meets the performance requirements of commercial flight users.

In addition to stability and feasibility, there is also a speed indicator for file upload and download, which will be directly affected by network speed and disk read and write speed. The actual test results in the actual environment are shown in Table 1 below.

Table 1. Time-consuming test of file transmission in flight test database system based on big data

Test item	Disk reading and writing(Mb/s)	Expected rate(Mb/s)	reality (Mb/s)
upload	80	40 -50Mb/s	60 -70Mb/s
download	80	40 -50Mb/s	60 -70Mb/s

It can be concluded that the actual rate of file upload and download can reach 60 -70Mb/s per second, which can meet the performance requirements of commercial flight customers for file upload and download. The flight test database system based on big data basically meets the functional requirements. It provides data support for flight test safety.

Experiment on whether the performance is different when the number of partitions is different, that is, the number of tasks is 16, 32 and 64 respectively. The results are shown in Figure 4:

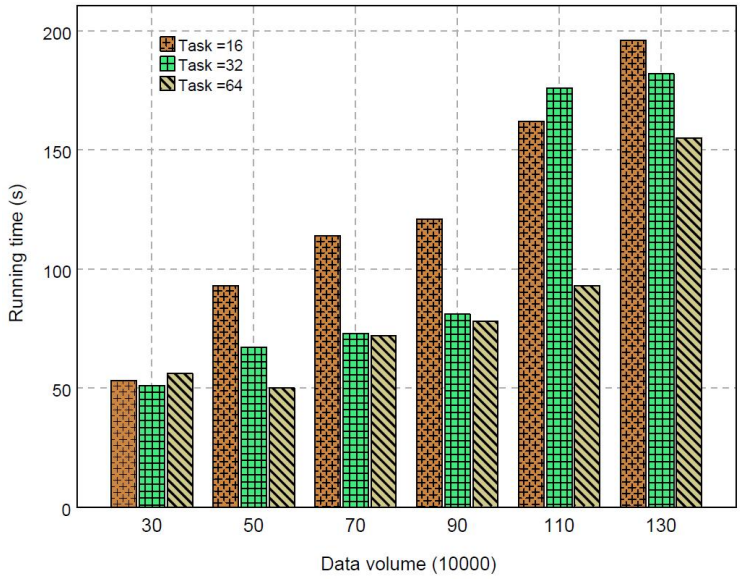

Figure 4. Running time under different task numbers

When a single data set is 300 thousand, the performance is similar, but with the increase of data volume, the performance difference is obvious. This is because, in theory, when the amount of data is small, the calculation time required is relatively short, which can not reflect the advantages of multi-task parallel; When the amount of data is more, the advantages of multi-task parallelism can be fully reflected, so the overall running time will be shorter and the performance will be better. The experimental results obtained in practice are also in line with the theoretical research of this paper.

4. CONCLUSION

The research of flight test database system makes full use of modern computer and its network application technology and the concept and theory of hierarchical relational database, collects and manages flight test data and technical data generated during flight test, and establishes a database management and application system for flight test data of corresponding experimental objects and related test equipment. This system adopts a C/S structure based on WEB technology, which can ensure the flexibility of the system in development, as well as meet the speed and breakpoint continuous transmission requirements of the system in terms of large files and multiple files. It is very suitable for the current business management situation of Civil Aircraft Test Flight Company with multiple nodes, multiple users, and multiple roles. At the same time, a Spark based multi-channel spatial connection iterative query algorithm was proposed.The system test results show that the actual rate of file upload and download can reach 60 -70Mb/s per second,

which can meet the performance requirements of civil aircraft flight test organization for file upload and download. The flight test database system based on WBE technology basically meets the functional requirements. The database design idea can be used for reference by flight test units and civil aviation units, and provides data support for flight test safety management.

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