Journal of Electronics and Information Science (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jeis.2024.090321
ISSN 2371-9524 Vol. 9 Num. 3

Design and Application of Experimental Data Management System Integrating Remote Monitoring and Historical Data Analysis

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Keywords: Ship impact explosion test, Test data management system, Remote monitoring, Data analysis, B/S

Abstract: In order to solve the problems of scattered data storage, difficult management and low data utilization in ship impact and explosion test, a test data management system integrating remote monitoring and historical data analysis is designed and implemented in this paper. The system adopts the hybrid architecture mode of B/S (browser/server) and C/S (client/server) to give full play to the advantages of the two architectures. VUE, ExtJS, Java, Python and other advanced technical frameworks and programming languages are applied in the system development process to ensure the high efficiency and flexibility of the system. The core function modules of the system include test task scheduling, data storage and management, data analysis, resource allocation, knowledge management and system maintenance. Through these modules, the system not only realizes the systematic management of the test data, but also supports the flexible expansion of the analysis algorithm to adapt to the ever-changing test requirements. The test results show that the system effectively solves the decentralized problem of data storage and management, and significantly improves the standardization and utilization efficiency of data management. The integration of remote monitoring function makes it possible to collect and process real-time data, and at the same time, to conduct in-depth analysis with historical data, which greatly improves the comprehensive application value of data. The implementation of this system has promoted the improvement of the management level of ship impact and explosion test data, and provided strong support for the research and application in related fields.

1. Introduction

As an important means to evaluate the impact resistance of ships in extreme environment, the ship shock explosion test not only plays a core role in the process of ship design and improvement, but also provides an important technical basis for improving the overall safety of ships. The large amount of data generated during these trials is not only a key resource for improving the impact resistance of ships, but also has an indispensable value for advancing the development of related

technologies. Therefore, how to manage and use these test data scientifically and effectively has become a key topic to improve the test efficiency, data quality and its application value.

At present, the research mainly focuses on data collection, transmission, analysis and result prediction, but the research on standardized and systematic management of test data is still insufficient. The existing test data management system is faced with multiple challenges such as scattered data storage, complex process management and low data utilization rate, and the research and practice in these aspects provide us with valuable reference. The monitoring data management system for geographical conditions of Shandong Province designed by Liu Xianyin successfully realized multi-version control of geographical information data by constructing spatiotemporal data model and using time axis for data management. However, because the system was based on C/S architecture, the flexibility of data sharing and access was poor. The test data management system developed by Wu Xiangfu and others for the climatic environment of the aircraft laboratory combines the B/S and C/S architectures to improve the management capabilities of test projects, processes, resources and data. However, due to the use of Oracle relational database, the warehousing and query efficiency of data may be affected when it deals with a large number of short-term data. In addition, the ship intelligent terminal data management system designed by Wang Ying based on big data technology, although it has excellent performance in data collection, storage, decryption and analysis, it still has certain shortcomings in the application level of data processing and analysis.

In view of the limitations of the existing system, it is particularly important to establish a comprehensive data management system for ship impact and explosion test. The system not only aims to optimize the storage and management of data, improve the efficiency and quality of data processing, but also provides solid technical support and guarantee for the research and application of ship impact resistance by integrating advanced technical means. Through the implementation of this system, the problems in data management will be effectively solved, and the technical progress in the field of ship impact explosion test will be further promoted.

2. Relevant Research

In the study of C Jake, remote monitoring technology was used to conduct in-depth analysis of the usage data of CPAP devices [1], and zero inflation negative binomial regression model was adopted to explore the relationship between patient characteristics and the number of days used, demonstrating the practicability of how to optimize the medical management system by using remote data. The findings revealed that only 46% of patients on long-term treatment were able to fully comply with the treatment regimen, and adherence decreased significantly in the first 90 days of treatment. B Casper's research explores the key success factors in effectively integrating real-time monitoring technology into test data management systems [2]. The study systematically analyzes the advantages of real-time monitoring, such as immediate data feedback and dynamic adjustment, and explores the challenges and limitations that may be encountered during implementation.

Y Kou's research proposes a novel data management approach specifically tailored to the needs of backfill experiments [3]. The system requirements of experimental business process modeling and multidimensional data query are analyzed in detail, and a number of system functions including experiment management, data query and knowledge base construction are designed. This method provides a systematic solution for the data management system of backfill experiment, especially in the processing of complex experimental data shows its high systematization and practicability.

Xiong's research focused on designing an experimental information management system, which included modules for historical data storage, data screening and processing, and data modification

and generation [4]. By combining historical data analysis and real-time monitoring, the system effectively improves the processing and application efficiency of experimental data. This study emphasizes the importance of system integration and data processing ability in experimental data management, and provides effective technical support for comprehensive management of complex data.

TD Paul's machine learning-based social threat filtering method (MLSTF) collects real-time data through smart wearable devices [5] and uses Internet of Things technology to transmit the data to remote servers for analysis. The core of this approach is to improve the security and accuracy of the system through real-time data monitoring and machine learning algorithms, demonstrating the potential of advanced technologies to protect users from social media threats.

A Konak studied the application experience of the Rucio system developed by CERN in SPD experiments, emphasizing the long-term importance of data storage and management in scientific experiments [6]. As a storage and processing solution for large-scale experimental data, Rucio system supports long-term effective management of experimental data and ensures data integrity and traceability. Y Lai proposed a new energy management system aimed at the energy consumption of liquid-cooled data centers [7]. The system uses an energy predictor, resource controller and resource configurator to optimize energy use, and utilizes the S3C2440A microprocessor and particle swarm optimization algorithm to improve system performance. H Liu's research explored the solution of combining edge computing with data management tools [8], and realized low latency services for Internet users by optimizing data requests and responses at the edge layer. This scheme provides efficient data processing and service optimization methods for data management system by improving data accuracy and real-time performance.

These research results provide theoretical support and practical experience for this research, and significantly improve the performance and application effect of the system by integrating advanced monitoring technology and data management tools. These advanced researches not only enhance the scientificity of the system design, but also provide innovative ideas and methods for the future test data management.

3. System Design and Implementation

3.1 System Requirement Analysis

The ship impact explosion test is faced with many challenges, such as long test period, short measurement time, numerous acquisition channels, large data volume and dispersed resources. These characteristics put forward higher requirements for the data management system, so it is necessary to design a unified and standardized test data management system to ensure the effectiveness of test planning, improve the efficiency of data sharing and utilization, and ultimately reduce the test cost.

In order to meet these requirements, the system must be able to fully manage the test task, which includes detailed records of the source, type, planning, scheduling, responsible personnel, and task status. By providing the functions of task creation, decomposition, assignment and overview, the system can realize the whole process monitoring and management of test tasks, so as to improve the efficiency and accuracy of task management.

In the aspect of data storage, the system needs to establish a data storage model that conforms to specifications to deal with the characteristics of shock and explosion test data. These data include test model, instrument parameters, environmental data, calibration information, original measurement data, test results and related algorithms. The system should have the ability to support the import and export of large-capacity data to ensure the standardized storage and management of data, so as to ensure the integrity and accessibility of data.

In order to improve the visualization effect of data, the system needs to visually display the test data through visualization tools such as charts and curves. In this way, users can quickly understand the changes in the data and have a clearer grasp of the trial process. This graphical presentation not only enhances the readability of the data, but also helps users better analyze the test results.

In terms of data analysis function, the system should provide a flexible algorithm library interface to support the input and dynamic loading of algorithm programs written in a variety of programming languages (such as Python, Matlab). The system needs to have the functions of algorithm verification, permission management and algorithm library to ensure the accuracy and flexibility of data analysis and improve the efficiency of test data analysis.

The management of test resources is also an important part of the system function, and the system should fully manage all the equipment, instruments and samples related to the test. Specifically, the system needs to provide the functions of ledger information management, measurement reminder and information statistics for these test resources to ensure the efficient use and maintenance of test resources, and thus improve the reliability of the test.

The system must have a perfect knowledge management function, and all the documents related to the test, such as software programs, standards, test Outlines and reports, are centrally managed. By providing the function of query and download of documents, the system can realize unified management and convenient access to knowledge. In addition, the system also needs to include user management, permission control, logging and backup management functions to ensure the security of the system, data integrity and operational traceability, so as to provide comprehensive technical support for the study of the ship's anti-impact performance.

3.2 Overall System Framework Design

The business process of ship impact explosion test is relatively complex, usually from the mission planning stage to the end of the test, which makes the management and execution of each stage need a high degree of accuracy and coordination. Because the data generated in the test process has the characteristics of huge volume, very short collection time and complex and diverse data formats, it is very important to design and build an efficient data management system. The system must be able to meet the whole management needs of the test task from planning to execution, and ensure that all links have traceability, so as to ensure the smooth progress of the test task. Through the unified data storage and sharing management mechanism, the system can not only greatly improve the utilization efficiency of test data, but also effectively reduce the overall cost of the test, and finally provide strong support for the in-depth study of the ship's anti-impact and anti-explosion performance.

In terms of the choice of system architecture, it is particularly reasonable to build on the digital platform TDM (Test Data Management), because the platform can ensure that the system can achieve efficient management through a unified data source, a unified database and a unified user interface. A hybrid architecture of B/S and C/S is used in the system design, which can take into account the actual needs of different modules. B/S architecture allows the client to interact directly with the server through the browser, thus realizing the unlimited number of system users and providing a solid guarantee for long-term stable use; At the same time, the server side is mainly responsible for processing client requests, executing complex business logic, and feeding the results back to the client. The adoption of C/S architecture is to meet the demand for efficient calculation in the process of test data analysis, so that complex algorithms can be flexibly invoked in the system and adapt to different test scenarios.

In order to cope with the diversified requirements of test data storage, the system design adopts the storage scheme of Oracle and MongoDB, and makes full use of the technical advantages of the

two databases. Oracle, as a powerful relational database, is mainly used to store structured data, including small-scale data such as test project information, test conditions and environmental data, while MongoDB, due to its high performance and flexibility, undertakes the storage task of unstructured and large-scale data. Especially when dealing with the large amount of measurement and file data generated during the trial process, MongoDB demonstrated its excellent storage and query capabilities. Through this dual-database storage scheme, the system can not only ensure the efficiency and stability of data storage, but also have excellent scalability to meet the challenges of increasing data volume and complexity in the future.

In addition to data storage and management, the system also needs to have powerful data analysis and display functions. Based on the large amount of data generated during the test, the system will display the trend of these data through graphical means to help users intuitively observe the test process and find potential problems in time. At the same time, the system also supports a variety of programming languages including Python and Matlab algorithm call function, allowing users to upload customized algorithms according to actual needs, and through the system's algorithm library for centralized management, such a design can greatly improve the flexibility and accuracy of data analysis. Ensure that users get the best computational efficiency and analysis results when processing data.

In order to ensure that the test task can be carried out smoothly, the effective management of the test resources is a link that cannot be ignored in the system design. Through the comprehensive management of test resources, the system can not only realize the accurate scheduling of test equipment, instruments and related resources, but also improve the use efficiency of test resources and reduce resource conflicts and waste in the test process by means of reservation function, verification reminder and resource statistics. Related to this, the system also needs to comprehensively manage the test knowledge to ensure that the standard specifications, test reports and technical documents related to the test can be uniformly stored and classified through the system, which is convenient for subsequent users to quickly query and download, so as to provide knowledge support for subsequent scientific research work.

4. System Test and Evaluation

4.1 Remote Monitoring and Data Management

The design goal of remote monitoring and data management system is to manage all kinds of data generated in the course of ship impact and explosion test comprehensively and effectively, so as to ensure the systematic collection, scientific classification, standardized storage and efficient use of data. Through the data management module with complete functions, the system collates and archives a large amount of data generated during the test in detail, and analyzes the data based on multiple dimensions, providing solid data support for the study of the ship's anti-impact performance. First of all, data collection and storage is the core part of the whole management system. According to the characteristics of the ship impact and explosion test, the system builds a number of databases including the test model, test equipment, test configuration, test process, test environment and test results. Each database is designed according to the special needs of the test, storing the detailed parameters related to the test model, the operation instructions of the equipment and the performance calibration information, and recording the specific content of the test layout, the measurement channel configuration, and the communication setting of each test. In addition, through the test process database, the system also records and manages each step in the test process, including the person in charge, task progress, work results, etc., and ensures the transparency and controllability of the whole process through process solidification. For the test environment, the system records the environmental information related to the test in detail, such as water temperature,

water flow direction, climate conditions, etc. These data are stored in the database in a structured form, providing reliable background data support for the subsequent analysis of the test results. At the same time, in the test results database, the system not only standardized storage of the original data to ensure that the data cannot be modified, but also stored the processed test results, and supported the management of multimedia data including pictures, videos, etc., using the combination of structured and unstructured data to ensure the integrity and reliability of the data.

In order to further improve the efficiency and convenience of data use, the system provides users with a variety of data query and browsing functions, users can quickly retrieve the required test data through the system's built-in single-condition query, multi-condition combination query and fuzzy query. The system also supports navigation trees built by project, test task and test conditions to help users browse and manage test data at different levels. Structured data can be directly viewed online, while unstructured data, such as pictures, documents and videos, can be previewed through third-party plug-ins. In addition, the system also provides powerful data classification and statistics function, users can automatically classify and summarize the data according to different dimensions such as test time, test type, test state, and test leader, and generate various forms of statistical charts including bar chart, pie chart, line chart, etc., to further enhance the intuiteness and operability of data analysis. These visual statistical results not only facilitate the in-depth analysis of test data, but also support the export and saving of pictures, which greatly facilitates the sharing and display of data by users. Through the integrated function of remote monitoring and data management system, the whole life cycle management of the entire test data can be realized. The system not only greatly improves the reliability, integrity and traceability of the data, but also provides rich and accurate data support for the subsequent decision analysis.

4.2 Test Method and Result Analysis

One of the core functions of the test data analysis system is to integrate a variety of algorithms into the system in the form of plug-ins, so that users can dynamically load the algorithm program and quickly call it during use, so as to effectively improve the overall efficiency of data processing and analysis. The operation of the whole algorithm is mainly concentrated in the client side, and all the calculation results are automatically submitted to the data display interface, so that users can intuitively view the analysis results and evaluate. In the process of data analysis, users can query the list of historical tasks on the client interface, select the test tasks to be further analyzed, and obtain the corresponding data files from the test data management terminal. In order to ensure the compatibility of data transmission and adapt to different environments, the system uses the default SMB protocol in the Windows operating system to share data. The SMB protocol serves as the bridge of information transmission between the client and the server, enabling users to quickly share and transfer files on the LAN.

In the aspect of algorithm management, the system allows users to upload customized algorithm files, and automatically checks the integrity and validity during the upload process to ensure that the uploaded algorithm program can run correctly. After verification, the algorithm file will be securely stored in the algorithm library for data analysis clients to call. In the actual data analysis, the data analysis client is written in Python, using Python's dynamic loading technology, users can flexibly extend the analysis function, and ensure that the required algorithm program can be dynamically loaded when the algorithm is called. The whole call process is interactive through WebService interface, and the data analysis client obtains the required algorithm program from the algorithm library through the request-feedback mechanism, and finally realizes the algorithm call and data efficient processing. In addition, the system supports various forms of analysis results display, and allows users to safely save the processed results to the local, to meet the requirements of subsequent

analysis and audit.

The system records the number, name, and person in charge of the device in detail in terms of the device resource management function, and allows users to initiate the device use process through the online application form, ensuring that the use of each device has a detailed record. The system will automatically record the electronic signature of the borrower and the user, and provide the user with the functions of modifying, deleting and querying the equipment information, which simplifies the management process of the equipment. At the same time, the system also has a powerful knowledge management function. Through the classified management of test templates, technical standards, technical documents and other materials, the system provides version control and full-text search functions, which is convenient for users to quickly find and trace relevant documents, and improves the overall efficiency of knowledge management.

In terms of user management functions, the system is responsible for maintaining the basic information of each user, and assigning different access rights according to roles to ensure the security and controllability of the system. The rights management module of the system assigns users to different roles based on preset roles. Each role has corresponding operation rights. In addition, the system uses the log management function to record all operations performed by each user in the system in detail, so that audit administrators can monitor the system running status in real time and discover and deal with potential security risks in a timely manner. The system also supports automatic backup and recovery of structured and unstructured data. Regular backup operations ensure the security and integrity of all data in the system to avoid data loss or damage.

The system adopts the combination strategy of Oracle database and MongoDB in database design, which are used to store the basic information of the project, task details and test data. Through reasonable database structure design and optimization, the system can not only efficiently store all kinds of information related to the test, but also ensure the consistency and integrity of data processing, so as to ensure the data management process of the whole system is more efficient and reliable.

The system supports users to upload custom algorithms according to the system's preset library rules in actual application scenarios, and calls these algorithms flexibly through Python dynamic loading technology, ensuring that each user can effectively expand and call functions according to their own needs. In order to further ensure the security and reliability of the uploaded algorithm files, the system introduces the MD5 check mechanism to ensure that the validity and consistency of each file are strictly checked before being stored, ensuring the stable running of the system and improving the user experience.

5. Conclusion and Prospect

Through the development of the crew fatigue monitoring data analysis system, this paper has achieved remarkable results in the test task coordination, data recording and processing, analysis ability expansion, resource allocation, knowledge accumulation and system operation, etc. The system test results show that each function module can run stably and achieve the initial goal. In addition, based on the standardized data entry mechanism and the application of Python dynamic loading technology, the system successfully realized the flexible call and dynamic expansion of the analysis algorithm, which greatly improved the adaptability and scalability of the system, not only to meet the current monitoring needs, but also to provide new inspiration and reference for the data management system design in related fields. However, in the face of the continuous growth of massive data and the need for further processing of complex data, there is still room for further optimization and improvement of future research. In the follow-up work, cutting-edge data mining methods such as deep learning model, statistical regression analysis and association pattern

recognition can be considered to fully mine the potential information in the data, further improve the data utilization efficiency and analysis ability of the system, provide intelligent support for more complex scenarios, and promote the system to play a role in a wider range of application environments.

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