Research on the Field Evaluation Technology of Airborne Test Data in the Mode of Flight Test Mission Surge

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Abstract. In order to meet the requirements of fine, reliable and efficient preparation at the flight test site, an airborne test data detection method was proposed. By obtaining the topology of the airborne test system, the analytic hierarchy process is used to quantitatively analyze the task support capacity of the test system, the airborne test data detection method based on the improved rule model is designed, and the remote control command state expectation-response matching algorithm is established to improve the digital level of the test work at the test site. Based on the airborne embedded platform, a set of test system data inspection and maintenance platforms is developed. The system has been installed and applied in multi-type testing machines, which greatly improves the on-site detection efficiency of airborne test data, realizes the decoupling of on-site test preparation of the testing machine from the test supervisor, allows the on-site supervisor to focus more on exception handling, reduces the impact of test failures on the test flight task, and reduces the on-site detection and evaluation time of airborne test data by more than 70%.

Keywords: task surge, hierarchical analysis, rule model, remote control, graded management

1 Introduction

The results of the detection and evaluation of airborne test data are an important determinant of on-site flight test decisions [1]. At present, scientific research flight test tasks have the following characteristics: The number of testing machines has increased significantly, requiring on-site test engineers to achieve high efficiency work quality; The rapid growth of test flight sorties requires reducing the working pressure at the test flight site and reducing human errors; The continuous improvement of the test point model requires an increase in the correlation level between the parameter state and the task requirements. In the face of the new task situation, it is urgent to improve the digital level of the test site test work, and meet the fine, reliable and efficient work requirements of the test guarantee and the flight test task in the mode of task surge by standardized, refined and efficient means.

In view of the requirements of on-site flight test mission support under the new form, this paper proposes an airborne test data detection method, which upgrades the existing test site working mode from various aspects such as evaluation methods, detection methods, and control methods, in order to solve the bottleneck that restricts the on-site mission test support capability, so as to achieve the purpose of improving the on-site test support capability of the test flight mission under the new situation [2].

2 Schematic Design

2.1 Overall Scheme Design

The main function of the airborne test system status detection and maintenance platform is to detect the operating status of each subsystem of the test system, which mainly includes: the operating status of the collector, recorder and telemetry subsystem, and the GPS and sensor adjustment subsystem reflect the operating status through the parameters of the collector. Through the monitoring platform, the state of the collection, recording, telemetry, GPS, and sensing adjustment subsystem is completed, the rapid status report of the test system is realized, and the online configuration of telemetry frequency points can be realized, so as to realize the rapid maintenance of the status of the test system. This is shown in Figure 1.

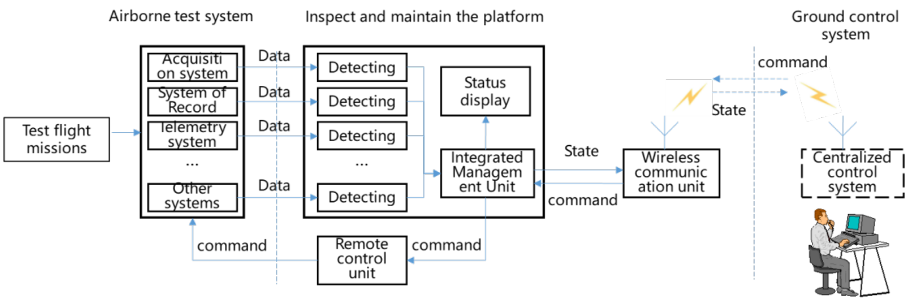

Fig. 1. Overall scheme diagram.

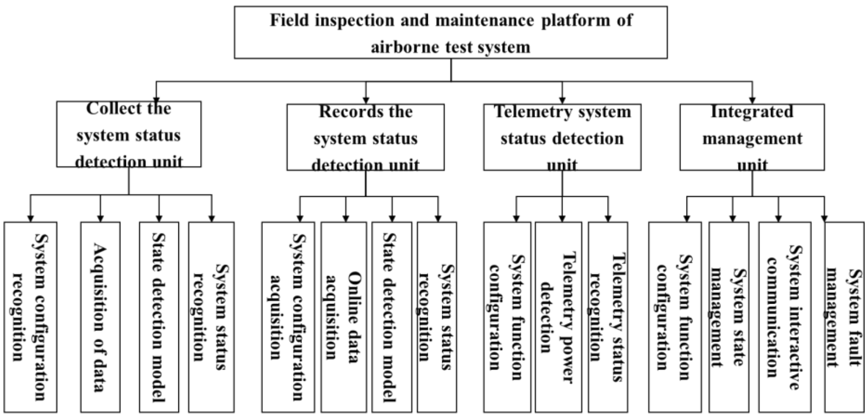

Fig. 2. System function composition.

Through the establishment of the field detection platform of the airborne test system, the model algorithm is used to detect the airborne test data, obtain the system status evaluation index and feedback, and support the fine, reliable and efficient work requirements of the test flight field test. The on-site detection platform of the airborne test system mainly consists of four parts: acquisition system inspection unit, recording system detection unit, telemetry system detection unit and system integrated management unit. The function composition of the system is shown in the figure 2:

2.2 Health Status Evaluation Method of Test System Based on Hierarchical Analysis

Typical airborne test systems mainly include a signal sensing layer, signal acquisition layer, data exchange layer, transmission application layer, etc., which is characterized by complex system cross-linking structure and clear data flow direction. Traditional function-based hierarchical division methods make it difficult to describe the membership relationship between different states, and cannot meet the requirements of efficient evaluation of system state. It can be seen from Figure 3 that the airborne test system has a complex topology but a clear data flow direction. Based on the data flow direction of the airborne test system, a five-layer state evaluation index is established and the membership relationship between states at each level of the system is clear, which is conducive to state evaluation and analysis.

The accuracy of status evaluation is subject to the weight of indicators. As a subjective weighting method, the analytic hierarchy Process (AHP) determines its weight accuracy by the prior knowledge of experts [3]. In order to improve the accuracy of weight indicators, a combination of subjective and objective weighting methods is adopted to improve the accuracy of weights [4]. This is shown in Figure 4.

ω_i is the combined weight, which is suitable for different evaluation tasks by adjusting the validity ratio. By synthesizing the weight set of four layers of status evaluation indicators, the influence of different systems, devices, modules and sensors on system health status can be obtained [0, 1]. According to whether each state is healthy or not, and its influence degree, the quantitative analysis of the health state of the test system is realized.

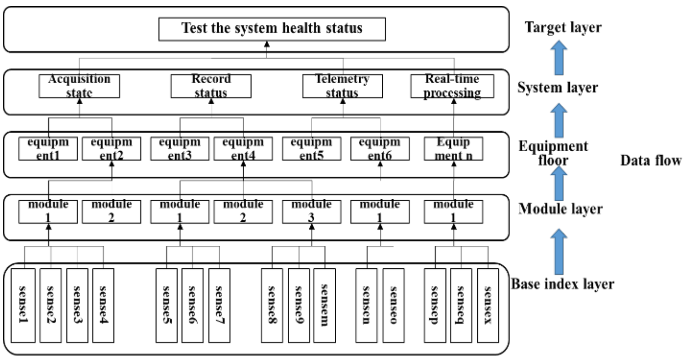

Fig. 3. Test system five-level state evaluation index.

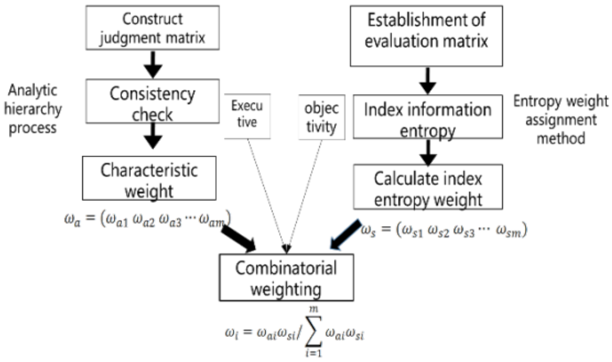

Fig. 4. Combinatorial weighting.

2.3 Test Parameter Detection Method based on Improved Rule Model

In order to obtain good interpretability and detection classification performance at the same time, a test parameter detection method based on a rule representation learner is designed. By extracting the objective relation and law between the test parameters, the analytical model is established to realize the automatic detection of the test parameters. This is shown in Figure 5.

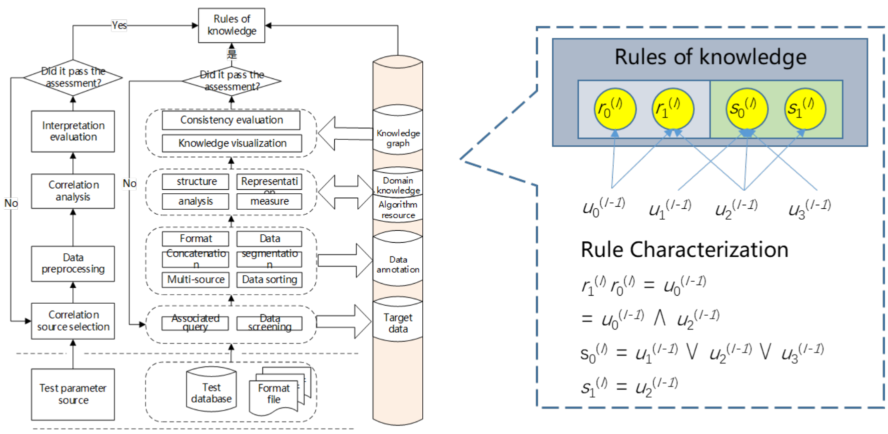

Fig. 5. Schematic diagram of typical rule model establishment.

Parameter Screening. Aiming at the problem that the identification of a single parameter state is easily affected by the state of the carrier, the correlation analysis algorithm is used to analyze the correlation degree among parameters, obtain the associated parameter group, and improve the accuracy and applicability of the model through multi-parameter fusion analysis. The parameter screening process is as follows:

According to the target parameter xt, the parameters are selected and the primary parameter group is established, A={x_1, x_2, …, x_n};

The correlation index between each parameter and the target parameter xt is calculated, C={c_1, c_2, …, c_n};

According to the calculation results, the correlation index threshold is selected and the parameter groups are screened, $c_i > c_{(t\text{-threshold})}$;

The parameter whose correlation indicator is greater than the threshold is selected and the associated parameter group for subsequent analysis is set up, B={x_1, x_2, …, x_m};

Data Reconstruction. To solve the problem of inaccurate detection and identification of sub-class data caused by unbalanced distribution of parameter values, the parameter values are classified. By increasing the residual weight of sub-class data, the importance of different categories of data is balanced, and the accuracy of parameter identification is improved.

The value distribution of target parameter xi is obtained, $x_i = \{x_{i1}, x_{i2}, \dots, x_{il}\}$;

The x_i values are divided into k classes, $\{a_1, a_2, \dots, a_k\}$;

The quantity of each type is obtained, $\{l_1, l_2, \dots, l_k\}$;

The residual value is modified to increase the residual weight of muscle data, $\omega_i = \sqrt[t]{\frac{l-l_i}{l}}$.

Model Verification. Taking the outlet pressure of an engine compressor as the target parameter, the model algorithm is verified by selecting the associated parameter group and extracting the implicit association rule.

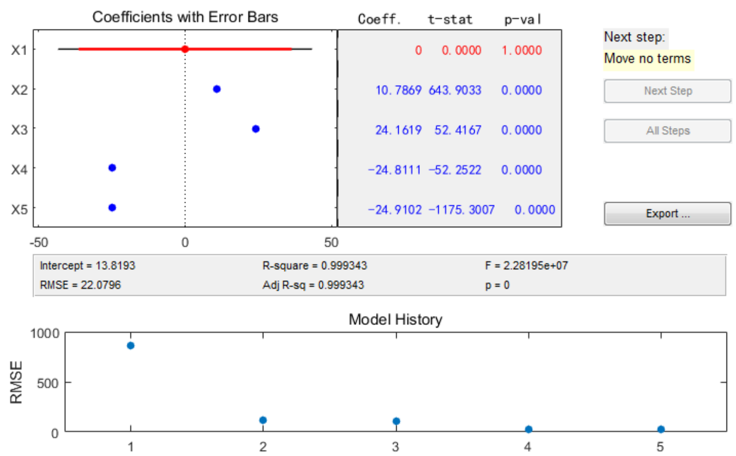

Fig. 6. Training process schematic based on improved rule model.

This is shown in Figure 6. The results show that the model can adapt to the state change of the carrier and improve the accuracy of the test parameter detection.

2.4 Remote Control Technology of Airborne Test System Based on Control Response

By establishing the control response model and designing the state expectation matching algorithm, the remote control detection unit is used as the carrier to open the closed loop of remote control, detection and feedback of the test system. This is shown in Figure 7.

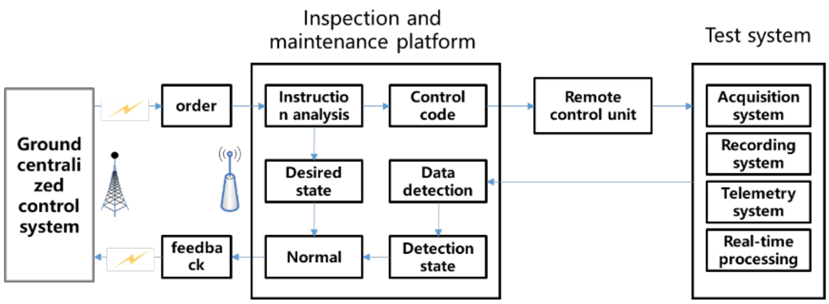

Fig. 7. Remote control loop diagram of airborne test system.

State Expectation Matrix. Based on the topological analysis of the test system, the remote instruction associated device set is established, and the key state feature vector based on the time-constrained response is extracted, which mainly includes the time constraint condition, working state, parameter state, etc., to form an n×m multidimensional expected state matrix, This is shown in Figure 8, which is used to describe the expected response characteristics of the remote instruction.

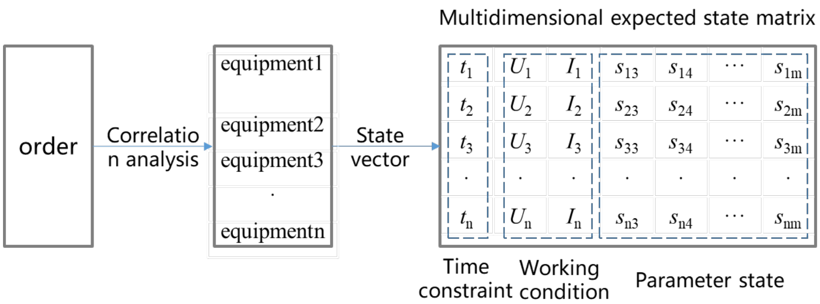

Fig. 8. Test the system instruction state matrix.

Response Matching Evaluation. Through the data detection algorithm model, the response characteristic matrix of the associated device set is obtained, the "response-expectation" matching operator is defined, and the multidimensional evaluation result of instruction response is obtained, so as to judge whether the remote instruction meets the expectation [5]. This is shown in Figure 9.

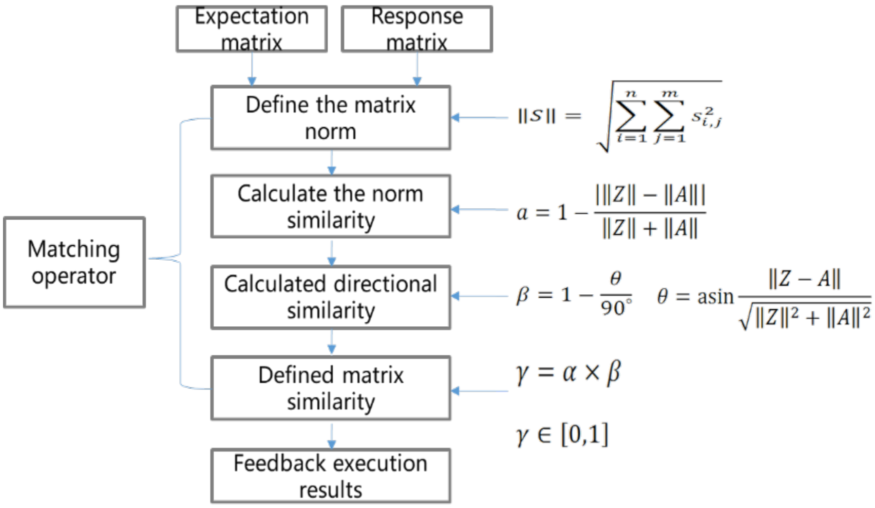

Fig. 9. Expected state matrix - response state matrix matching algorithm flow.

Taking a recording instruction as an example, the response-expected similarity level is calculated. The closer the similarity is to 1, the better the instruction execution result is, as shown in Table 1.

Table 1. Remote recording of expected and response states of instructions.

Remote recording instruction	Desired State	Detection status
Response time (%)	0.87	0.82
Record status	1	1
Fault conditions	0	0
Time synchronization status	1	1
Total recorded data rate (%)	0.21	0.22
Network data rate (%)	1	1.02
PCM data rate (%)	1	1.01
1553 data rate (%)	0.35	0.36

3 Experimental and Engineering Applications

On the basis of scheme design and key technology research, relying on embedded hardware systems, an airborne test data detection and evaluation application software is developed, and an experimental environment for verification is built. This is shown in Figure 10.

Firstly, the applicability of the airborne testing system status online detection platform to different types of airborne testing systems was verified, including KAM series collectors, aNTS collection systems, XMA collection systems, UMA collection systems, recording systems, and telemetry systems. The results are shown in Table 2:

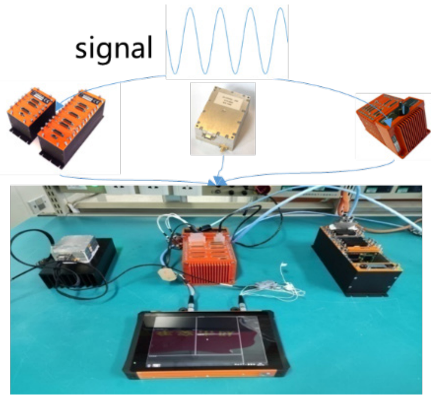

Fig. 10. Experimental verification and test environment construction.

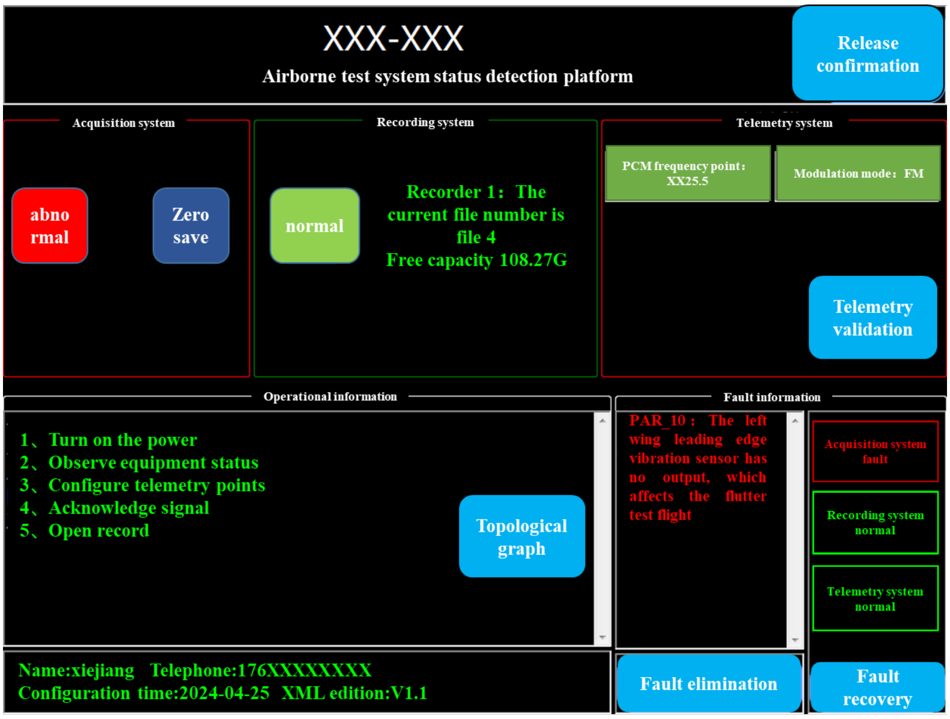

Fig. 11. Data detection result

Table 2. Adaptive verification - collection system.

Acquisition system	KAM	aNTS	XMA	UMA
PCM architecture	√	√	√	√
Network Architecture	√	/	√	√

Remote control commands support operations such as power on control, recording control, and telemetry frequency point setting for testing equipment. The response expectation matching algorithm can accurately reflect the execution effect of remote commands. The system supports real-time detection, with a parameter detection capability of over 3000, a fault recognition accuracy rate of over 98%, and the ability to provide information on task impact and solutions, and support rapid troubleshooting, as shown in Figure 11.

4 Conclusion

The algorithm designed in this article can quickly and accurately detect and evaluate test parameters, and is suitable for on-site detection and evaluation of airborne test data for various types of testing machines. The system has been applied on multiple test aircraft, and the model-based testing parameter detection and evaluation mode has achieved decoupling of on-site testing work from supervisors, allowing on-site engineers to focus more on anomaly handling and reducing the impact of testing failures on flight test tasks. The on-site detection and evaluation time of airborne testing data has been reduced by more than 70%.

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