A data-driven comprehensive evaluation method for Data Link

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Abstract. The data-driven data link comprehensive evaluation method is mainly used for heterogeneous business data management and intelligent analysis of test data in data link comprehensive testing. Heterogeneous business data management provides testing services such as storage, invocation, and management of testing data for testing terminals in the tactical data link comprehensive testing system. Intelligent analysis of test data provides intelligent data analysis and other testing services at the end machine, system, and system efficiency levels for testing terminals in the data link comprehensive testing system platform. The combination of field combat data and field data lays the foundation for building close to field scenario validation, saves testing and evaluation costs, and improves efficiency.

Keywords: effectiveness evaluation; Data link; Data analysis; Indicator system; Evaluation algorithm

1 INTRODUCTION

Traditional efficiency evaluation methods[1], including ADC method, exponential method, AHP method, etc., have slightly insufficient ability in processing massive information and cannot adapt to the requirements of the big data era. Data driven methods with artificial intelligence as the core are challenging traditional efficiency evaluation methods. Due to the dynamic and complex nature of combat effectiveness evaluation, it is difficult to effectively describe combat effectiveness through the construction of mathematics and the establishment of mathematical formulas. The data-driven combat effectiveness evaluation method does not require a deep understanding of the modeling mechanism. This method utilizes rich data generated in live combat exercises or combat simulation, based on statistical learning theory, and establishes a nonlinear relationship between input variables and output variables through learning from historical data. When new data is input, the effectiveness value can be automatically obtained, which is more suitable for the evaluation of combat effectiveness in high-dimensional, nonlinear, and complex live combat exercises. It helps to reduce decision-making errors and effectively improve the correctness, accuracy, and timeliness of decision-making.

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In the evaluation of data link combat effectiveness[2], the data link organically connects various combat equipment and relies on the collaborative operation of comprehensive information systems. It is difficult to construct descriptive mathematical models for the nonlinear and dynamic relationships between formations. The data-driven combat effectiveness evaluation method does not require a deep understanding of the modeling mechanism. It can determine the performance of the information system, identify weak links in the system, and improve the application effect of the system, Help improve effectiveness based combat capabilities. This project studies a data-driven method for evaluating the effectiveness of networked collaborative operations. Focusing on joint operations in theater of war, it focuses on the ability requirements of tactical collaborative tasks and constructs a hierarchical combat effectiveness indicator system oriented towards information advantages. To address the issue of comprehensive calculation of qualitative and quantitative indicators in combat effectiveness evaluation, a effectiveness evaluation method based on intelligent data analysis is studied. Combine typical combat operations to verify the effectiveness and rationality of the method.

Considering that the data link does not have a large number of accurate statistical data to calculate the model, and the relative fuzziness, multi-level and complexity of the data link effectiveness index, this paper synthesizes the analytic hierarchy process and fuzzy analysis method, combines the qualitative and quantitative analysis in the data link effectiveness evaluation, and synthesizes the index system hierarchically. And effective effectiveness evaluation results are obtained.

(1) Integrity principle

A complete index system is the basis for a comprehensive and correct understanding of command effectiveness. The established index system should not omit any important index. Based on the incomplete index system, it will inevitably lead to a one-sided understanding of things. However, the integrity of the indicator system is relative. In actual evaluation, in order to improve the efficiency of evaluation, it is also permissible to consciously omit some influential but secondary indicators. However, the choice of indicators should be determined according to the weight of indicators in the system.

(2) Principle of pertinence

The index system of operational command effectiveness of coastal defense artillery in complex electromagnetic environment should be put forward according to artillery information operations and reflect the operational characteristics of coastal defense artillery.

(3) Principle of completeness

In the index system of operational command effectiveness of coastal defense artillery, each index should not appear repeatedly, and any index that significantly affects the operational command effectiveness of coastal defense artillery should appear in the index attribute set, and the selected index should cover the range involved in the operational command effectiveness.

(4) Principle of independence

The indexes selected for the evaluation of operational command effectiveness of coastal defense artillery should be independent of each other as far as possible, and should not contain each other.

(5) Hierarchical principle

In the multi-index evaluation index system, different indexes are closely related and constitute an index category. Therefore, in practice, the indicators are often classified to form different levels, from the evaluation of the overall indicators to the lower indicators, and gradually decomposed into the lower sub-indicators. The purpose of decomposing an index is to obtain a more specific index for quantification. When the index is decomposed to a sub-index that can be generally calculated, the decomposition stops. In the evaluation, there are different classification results from different evaluation perspectives, but they must be able to form a hierarchical structure.

(6) Stability principle

Indicators must reflect the common attributes of command activities to meet the needs of operational command evaluation under different types, different times and different environmental conditions. In general, common experience and data developed in previous operations can be used as an intermediary to specify certain common factors and indicators. At the same time, the authority of the evaluation index system should be maintained, and the evaluation index should not be changeable. If it needs to be changed, the scope should not be too large, and it should not become too frequent, otherwise it will lead to confusion in command activities and affect the command effect.

2 PRINCIPLE OF DATA-DRIVEN COMPREHENSIVE EVALUATION OF DATA LINKS

By simulating and generating typical application scenarios such as sea air joint close range air support, establish a reasonable data link efficiency evaluation index system and evaluation methods. Establish an evaluation index system for effectiveness at different levels, including intelligence distribution, situational sharing, command and control, combat coordination, and weapon control. Research on the effectiveness evaluation model of data link system, and use scientific and effective evaluation methods to evaluate the combat capability of data link from the perspective of data link indicator system. Conduct a comprehensive analysis and evaluation of the combat effectiveness of data link systems and multi link integrated applications. By accessing the data management terminal, the relevant test data is parsed, encapsulated, and forwarded. The test data and test reports are forwarded to the data link comprehensive testing calculation and storage device, and the data is mined and analyzed to provide support for the diagnosis and optimization of data link equipment problems.

The data-driven methods[3] are divided into two types: scenario driven dynamic mode and historical data-driven mode.

The dynamic driving mode is to obtain data during the use of the test data link in the integrated testing system environment of the data link system, extract relevant indicators, establish an efficiency evaluation index system, select appropriate evaluation algorithm models, complete the efficiency evaluation of the data link, and process the test data and test reports uniformly through the data management terminal, stored in the data link integrated testing calculation and storage device.

The historical data-driven mode is when the data link performance evaluation tool extracts test and simulation data from the data link comprehensive testing calculation and storage devices through the data management terminal, restores historical combat scenarios, analyzes and processes them, and finally obtains the evaluation results without being connected to the data link system comprehensive testing system. As show in figure 1.

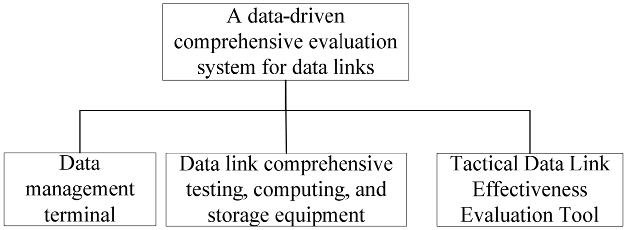

Fig. 1. Product composition diagram of data-driven data link comprehensive evaluation system

2.1 Tool Composition

The data-driven data link comprehensive evaluation system is mainly used for heterogeneous business data management and intelligent analysis of test data in data link comprehensive testing[4]. Heterogeneous business data management provides testing services such as storage, invocation, and management of testing data for testing terminals in the tactical data link comprehensive testing system. Intelligent analysis of test data provides intelligent data analysis and other testing services at the end machine, system, and system efficiency levels for the testing terminals in the tactical data link comprehensive testing system. The effectiveness evaluation and data mining analysis of tactical data links are typical applications based on intelligent data analysis and other testing services, which are implemented by testing terminals using testing methods to provide corresponding functions, as shown in Figure 2.

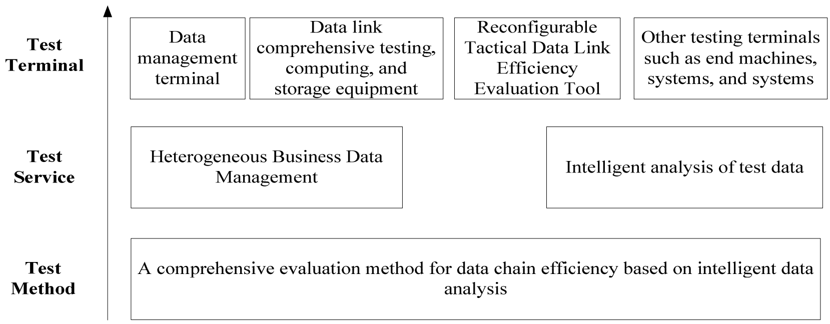

Fig. 2. Relationship diagram between testing methods, testing services, and testing terminals

2.2 Comprehensive evaluation process

The data-driven data link comprehensive evaluation system provides three testing applications: tactical data link effectiveness evaluation tool[5], data management terminal, and data link comprehensive testing calculation and management equipment. The connection relationship is shown in Figure 3.

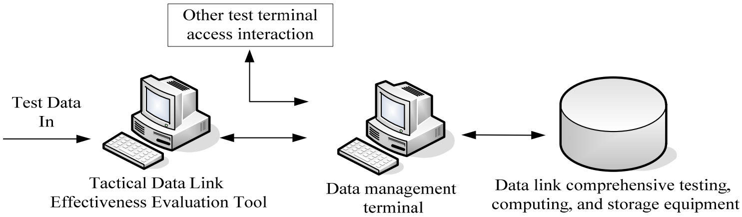

Fig. 3. Connection diagram of three testing applications

The testing workflow[6] is as follows:

(1) The tactical data link effectiveness tool is integrated into the tactical data link comprehensive testing system[7], generating combat scenarios to obtain test data, determining indicator systems and analysis evaluation criteria, developing effective evaluation methods, establishing evaluation models or algorithms, conducting testing calculations, and using a combination of qualitative and quantitative methods to provide data link effectiveness evaluation results;

(2) After processing the test data and results through the data management terminal, they are stored in the data link comprehensive testing calculation and storage platform;

(3) The data link comprehensive testing, calculation, and storage platform conducts statistical analysis and mining analysis on the stored data to determine whether the operational capability and effectiveness of the data link system meet the operational requirements, and provides optimization suggestions for the application of the data link system.

The tactical data link effectiveness tool mainly solves the problem of verifying and evaluating the effectiveness of tactical data link equipment[8]. It can be applied to the demonstration and effectiveness evaluation of data link system equipment systems, including evaluation models, evaluation methods, evaluation index systems, evaluation methods, etc., to achieve the evaluation of data link effectiveness.

The data management terminal has completed the unified access of data from various testing terminals, and the generated data types include real-time data packets (business data packets, general control data packets, general status data packets), analysis files of 2 types (Txt, Xml), and storage files of 3 types (audio and video, files, and images).

The data link comprehensive testing computing and storage equipment provides the infrastructure for computing and storage for the testing system platform[9]. It adopts a hybrid storage architecture for deployment, with a total of 8 servers to complete the storage, retrieval, management, and intelligent analysis of experimental data. It supports data management functions for data link testing projects, and provides visual analysis and commonly used machine learning algorithm modules for fault diagnosis and other application scenario mining and analysis.

2.3 Interface relationships

Each module provides specific functions[10], and interactions between modules are completed through specific interfaces. The interface provides users with a detailed description of how to interact with the module, without the need to understand the underlying implementation details. It also describes the usage environment (hardware platform, operating system, etc.) and performance of the component to the user. The main interfaces are as follows:

Support Ethernet interfaces such as integrated control terminals, platform simulators, and other testing terminals;

Support the use of database driven interfaces, such as JDBC, ODBC interfaces, and other database connection methods.

2.4 External interfaces

Support communication Ethernet connections for devices such as integrated control terminals, combat scenario simulators, platform simulators, protocol analyzers, portable comprehensive detectors, and broadband signal analyzers. The above devices are interconnected through Ethernet, with corresponding IP addresses and port numbers pre-set, as shown in Figure 4. The interface processing software for data-driven comprehensive evaluation of data links is responsible for receiving platform data from other platforms and performing corresponding processing functions, achieving data interaction with other platform network cable interfaces[11], and completing data reception and transmission between platforms through socket network protocol.

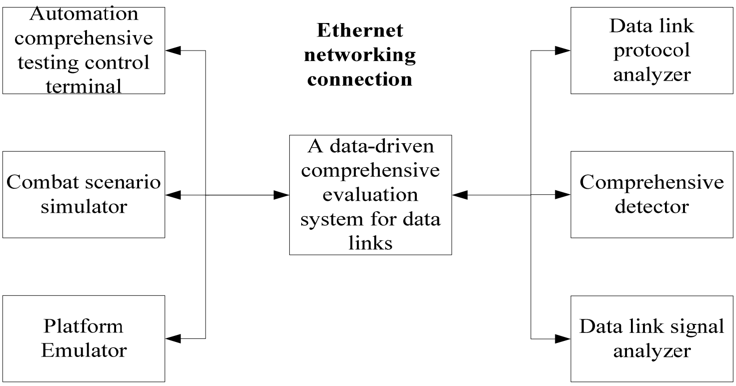

Fig. 4. External Interface Diagram

2.5 Internal interfaces

The The internal module interface of the data-driven data link comprehensive evaluation method is the tactical data link effectiveness evaluation tool, the data management terminal, and the data link comprehensive testing calculation and management equipment are connected via Ethernet, as shown in Figure 5.

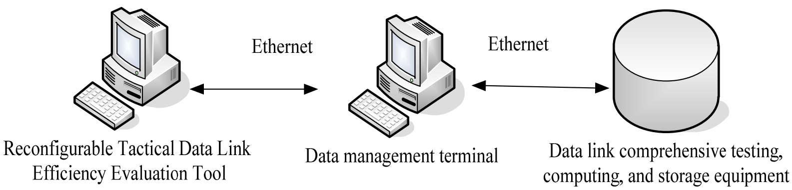

Fig. 5. Internal Interface Diagram

3 HARDWARE DESIGN SCHEME AND TESTING

The data-driven comprehensive evaluation method for data links includes tactical data link effectiveness evaluation tools, data management terminals, and data link comprehensive testing computing and storage devices. The hardware composition diagram of the data-driven comprehensive evaluation method for data links is shown in Figure 6.

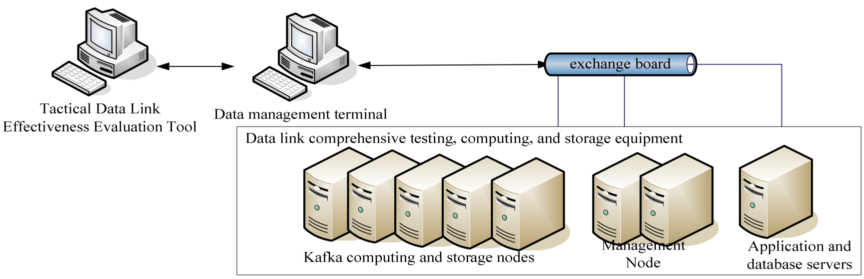

Fig. 6. Hardware composition diagram of data-driven comprehensive evaluation method for data links

According to the data link effectiveness evaluation index system given in Chapter 1, the judgment matrix A of the criterion layer and the judgment matrices A1, A2, A3 and A4 of the factors of the attribute layer are constructed:

$$A = \begin{bmatrix} 1 & 3 & 1 & 5 \\ 1/3 & 1 & 3 & 1/3 \\ 1/5 & 3 & 1 & 1/5 \\ 1 & 3 & 5 & 1 \end{bmatrix}$$

$$A_1 = \begin{bmatrix} 1 & 1/3 & 5 & 3 \\ 3 & 1 & 3 & 7 \\ 1/3 & 1/3 & 1 & 5 \\ 1/3 & 1/7 & 1/5 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix}$$

$$A_4 = \begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix}$$

From the square root method, the criterion layer weight W and the attribute layer weights W1, W2, W3, W4 can be obtained:

$$W = \begin{bmatrix} 0.38 & 0.16 & 0.07 & 0.39 \end{bmatrix}$$

$$W_1 = \begin{bmatrix} 0.26 & 0.53 & 0.16 & 0.05 \end{bmatrix}$$

$$W_2 = \begin{bmatrix} 0.75 & 0.25 \end{bmatrix}$$

$$W_3 = \begin{bmatrix} 0.75 & 0.25 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} 0.75 & 0.25 \end{bmatrix}$$

The result of calculating the characteristic value λmax and performing the consistency check is:

$$\lambda_{\max} = 4.06, CI = 0.02, CR = 0.022$$

$$\lambda_{\max 1} = 4.26, CI_1 = 0.08, CR_1 = 0.089$$

$$\lambda_{\max 2} = 2, CI_2 = 0, CR_2 = 0$$

$$\lambda_{\max 3} = 2, CI_3 = 0, CR_3 = 0$$

$$\lambda_{\max 4} = 2, CI_4 = 0, CR_4 = 0$$

The single factor matrix of fuzzy comprehensive evaluation is:

$$R_1 = \begin{bmatrix} 0.5 & 0.3 & 0.2 & 0 & 0 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \\ 0.3 & 0.4 & 0.2 & 0 & 0 \\ 0.4 & 0.4 & 0.1 & 0.1 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0.5 & 0.4 & 0.1 & 0 & 0 \\ 0.3 & 0.4 & 0.3 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.5 & 0.3 & 0.1 & 0.1 & 0 \\ 0.4 & 0.4 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 0.4 & 0.4 & 0.2 & 0 & 0 \\ 0.5 & 0.3 & 0.2 & 0 & 0 \end{bmatrix}$$

Then the total evaluation matrix A is:

$$R = \begin{bmatrix} 0.412 & 0.372 & 0.211 & 0.005 & 0 \\ 0.451 & 0.39 & 0.15 & 0 & 0 \\ 0.473 & 0.377 & 0.125 & 0.075 & 0 \\ 0.426 & 0.374 & 0.2 & 0 & 0 \end{bmatrix}$$

Then, the total evaluation result of the target layer is:

$E = W.R = \begin{bmatrix} 0.427 & 0.375 & 0.192 & 0.007 & 0 \end{bmatrix}$ According to the principle of maximum membership degree, the maximum value is taken as the final result of data link effectiveness evaluation. 0.427 is taken here, that is, the data link effectiveness evaluation result is "very good".

4 SUMMARY

The data-driven comprehensive evaluation method for data links mainly solves the problem of verifying and evaluating the effectiveness of data link equipment. It can be applied to the demonstration and effectiveness evaluation of data link system equipment systems, and provides the computing and storage infrastructure for the testing system platform, the operating environment of application software and algorithm tools, as well as functions such as data processing, storage, management, and invocation. In typical application scenarios such as sea air coordinated close air support, the joint database of outfield actual combat and infield simulation is established to verify the rationality and progressiveness of the data link comprehensive effectiveness evaluation method driven by data. Introducing this method into the effectiveness evaluation of real-world scenarios has achieved data-driven effectiveness evaluation and analysis, providing a new research approach for the effectiveness evaluation of weapon and equipment systems.

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