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Current Situation and Development Trend of Daily Workshop Equipment Inspection in Mechanical Enterprises

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Abstract: With the development of information technology, the manufacturing industry informatization process has been greatly promoted, and the intelligent data and technical support of the workshop originate from real-time production data acquisition technology, accurate information feedback and reasonable and effective production decisions, which greatly increases the load of the traditional center service processing system. The manufacturing industry is an important part of social and economic development, and it is also an important cornerstone of the country's rapid development and prosperity. The innovation of science and technology and the change of demand have accelerated the transformation of traditional workshop production from automation and digitalization to intelligent development. The main purpose of this paper is to analyze the current situation and development trend of daily workshop equipment testing of machinery enterprises. With the development of information technology and the acceleration of global industrial change, the Internet of Things technology, BD, blockchain technology and other new technology fields have gradually risen, the mutual integration and development of industries has been promoted, and traditional industries have been transformed and upgraded towards modern industries with new goals, new requirements and new environments to resist the impact, which has greatly promoted the development of production and manufacturing. In this paper, according to the characteristics of enterprise machinery and equipment, the equipment status pre-judgment maintenance software and system are established, and finally the experiment proves the effectiveness of the proposed algorithm for the detection and scheduling of workshop equipment.

1. Introduction

At present, the types and data structures of mechanical equipment data owned by enterprises are very complex, and traditional relational databases are difficult to support the storage of semi-structured and unstructured data. In addition, the traditional customized mechanical equipment data visualization method is time-consuming and requires highly professional operators [1-2]. In addition, K-Means clustering algorithm relies heavily on the determination of the initial center, and Gaussian mixture clustering algorithm relies on the distribution of data samples, which makes it difficult to cluster the mechanical equipment scheduling and maintenance center stably.

In relevant research, Nadaraja et al. discussed the results of numerical simulation to simulate the performance of propeller with or without oil cooler, and used unstructured grid to conduct three-dimensional (3D) numerical simulation of propeller in the rotating region [3]. The second-order upwind finite volume scheme is used to solve the three-dimensional Navier Stokes equations. A computational fluid dynamics solver is proposed to analyze the influence of thrust loss. Corpino et al. described the deployment strategy and orbit design analysis applicable to the inspection of spacecraft in orbit through reusable cube satellites [4]. The objective is to 1) determine the requirements applicable to the deployment of nanosatellites from the mothership, which is also the subject of the inspection, and 2) determine the solution to the flight path in the mission phase.

This paper analyzes the needs of the BD platform for CM and EM, and then analyzes the feasibility of the BD platform for CM and EM, and analyzes the workshop equipment detection system. In this paper, Hadoop and Spark are used as the technical support to realize the BD platform for engineering machinery EM, and the mechanical equipment of a group is used as the test data to complete a number of storage and computing services, and a set of convenient and fast front-end services for BD visualization are realized.

2. Design Research

2.1. Demand Analysis of Big Data (BD) Platform for Construction Machinery (CM) and Equipment Monitoring (EM)

The platform can be divided into data access storage module, data calculation and statistics module and data visualization module according to functional requirements [5-6]. Figure 1 is the functional design diagram of the platform.

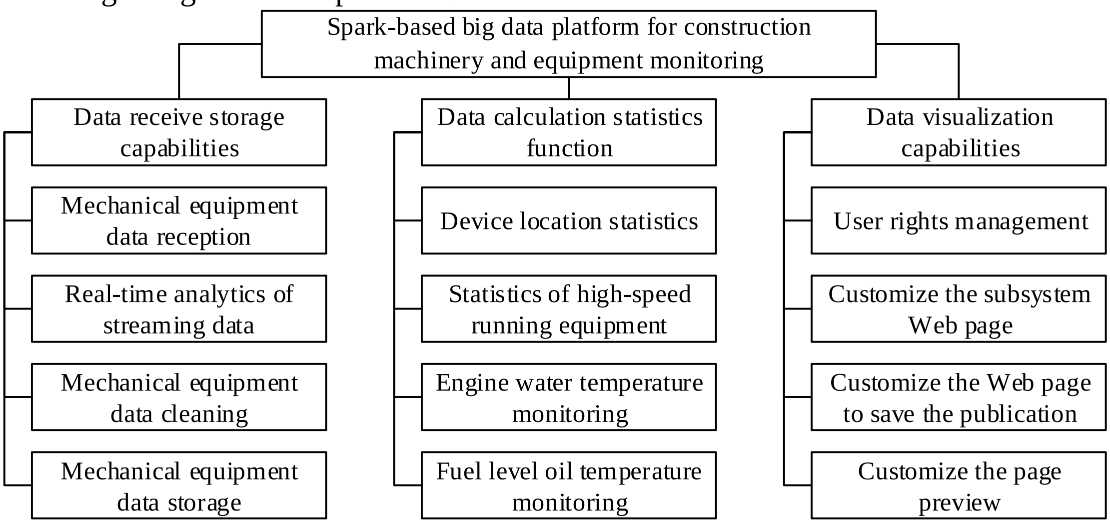

Figure 1. Design diagram of the functional module of the platform

In terms of management of CM and equipment, it is very important to directly show the parameters and operation status of each equipment to managers [7-8]. The construction of engineering machinery and EM BD platform must perfectly solve these problems. For the existing historical data and known real-time data formats, the following requirements are proposed from both functional and non-functional aspects [9-10].

(1) Functional requirements

1) Equipment location statistics

Considering that every engineering project in the enterprise may last for months or even years, and the CM and equipment used will also work on the same site for a long time, there will be a large number of unchanged or little changed equipment positioning data in the stored data, which has little value and reduces the data visualization efficiency in the data visualization transmission phase. Therefore, it is necessary to calculate the distance between each positioning point according to the equipment positioning information, and select a coordinate point as the representative point among the points with a very close positioning distance, so as to facilitate the subsequent data analysis [11-12].

2) Statistics of high-speed running equipment

For engineering enterprises, maintaining the CM and equipment will greatly reduce the production cost of the enterprise. Therefore, it is very necessary to count the high-speed running equipment. The monthly high-speed running equipment and the annual high-speed running equipment can be counted. The enterprise can take different maintenance strategies for different equipment according to the results of the statistics to ensure the health of the machinery and equipment .

3) Engine water temperature monitoring

For any mechanical equipment, the engine is the core part, and the maintenance of the engine is also the most difficult and costly. Therefore, it is of great significance to monitor the engine water temperature in real time, which can prevent engine failure to a certain extent. In addition, the monthly average temperature and annual average temperature of each equipment engine shall be counted, on which the corresponding equipment use strategy can be specified [13-14].

4) Fuel level and oil temperature monitoring

As the energy source of the equipment, it is essential to monitor the fuel level and temperature in real time. It is necessary to ensure that the fuel is kept in a relatively healthy state. In addition, it is also necessary to count the fuel consumption rate of the equipment (service time of each tank of fuel) and the average fuel temperature. These data indicators can provide reference for maintenance personnel, and can be used to troubleshoot problems that do not affect the normal operation of the equipment but will increase fuel consumption.

(2) Non-functional requirements

1) Highly reliable storage

For a wide range of large amounts of data, the BD platform must have the characteristics of highly reliable storage and the ability to quickly backup data to avoid data loss due to system failures. Mechanical equipment will continue to increase, and historical data will continue to accumulate, so the platform must have dynamic capacity expansion capability [15-16].

2) Efficient distributed computing

Whether it is offline statistics of massive historical data or real-time analysis of streaming data, the BD platform must ensure the efficiency and accuracy of calculation, and must avoid repeated calculation and missing calculation of data.

3) Easy visualization

As time goes by, enterprises will continue to have new businesses to join, and each new business must have its own visual web page and method, which requires BD platform to have a convenient and fast visual method, which greatly reduces the cost and development cycle of enterprise web page development.

2.2. Feasibility Analysis of BD Platform for CM and EM

Technical feasibility: This platform mainly involves BD technology and Java Web service technology. The platform bus includes data collection, data washing, data storage, data calculation and analysis, and data Web visualization [17-18].

Data collection mainly uses Socket to receive data from various sensors, and Kafka provides unified data processing services. Socket and Kafka are very mature and reliable technologies. The data storage part uses HDFS as the underlying storage of data, which supports data backup and dynamic expansion equipment. Hive and Hbase are used to provide external services such as real-time storage and offline analysis. Spark computing engine is used for data cleaning and data calculation analysis. The back end of the Web service uses the Spring boot microservice framework as the back end control, and the front end uses the Vue development framework. The above technologies are relatively mature frameworks and the platform builders have a basic grasp of these technologies. Therefore, the construction of this platform is completely feasible on the technical level.

Economic feasibility: the platform has no other hardware equipment except servers, and the entire platform is deployed on the server cluster, which requires low performance for a single server. Multiple low-cost servers can be used to build the cluster. The whole development process only uses Idea as a commercial software, but because of the student certification, Idea does not charge. In addition, all technologies used are community open source technologies. The entire platform only needs to pay for the server, so the construction of this platform is completely feasible on the economic level.

2.3. Adaptability

The fitness is an index used to evaluate the individual's superiority. All individuals in the group are evaluated and filtered through the fitness. The most basic evaluation indicator in the detection system is the maximum completion time, which is the key to affect the actual detection efficiency. Therefore, the maximum completion time is taken as the fitness measurement indicator, and the mathematical expression of the maximum completion time is Formula (1).

$$g(x) = Min\{\max(c_i)\} \tag{1}$$

The smaller the maximum completion time, the greater the fitness, which can transform the minimum optimization problem into the maximum optimization problem. In order to minimize the maximum completion time, the fitness function f (x) is designed as equation (2).

$$f(x) = \frac{1}{g(x)} = \frac{1}{Min\{\max(c_i)\}} \tag{2}$$

3. Experimental Study

3.1. Workshop Equipment Detection System

The workshop equipment demand is huge, so the annual inspection workload is very large. In the face of such a large number of workshop equipment, the quality of workshop equipment is controlled. The traditional detection mode mainly depends on manual operation, and the detection function is relatively simple. Therefore, the intelligent detection of workshop equipment is an inevitable trend. After the emergence of smart grid, the workshop equipment detection mode began to change, and the workshop equipment detection system came into being. The structure of the workshop equipment detection system is shown in Figure 2.

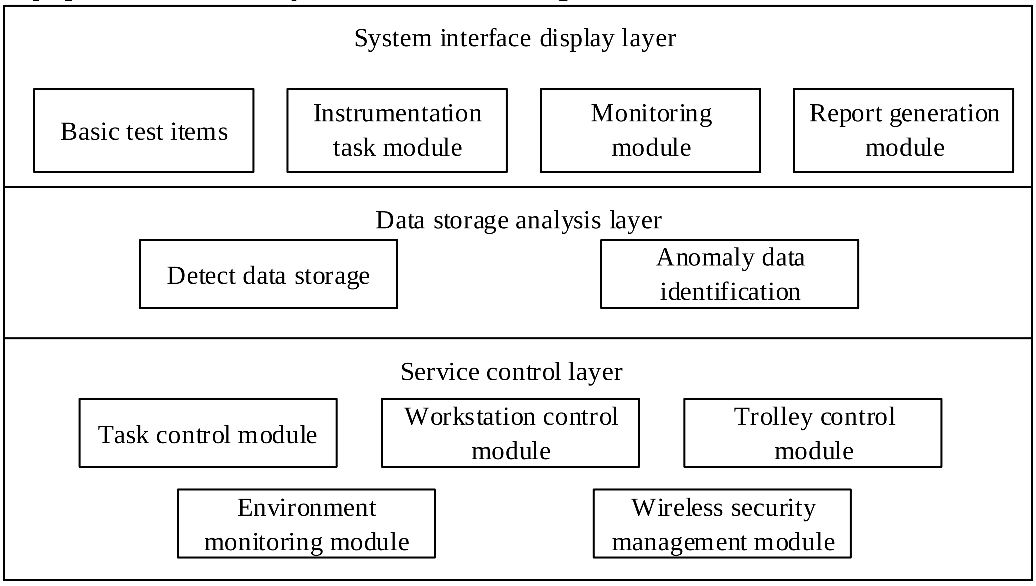

Figure 2. Workshop equipment detection system structure

The scheduling module is used to schedule the detection tasks in the system detection task module, so as to obtain a reasonable detection scheme with a small total completion time. Therefore, the following will briefly introduce the basic detection project modules and detection task modules involving detection tasks.

The test item data includes the voltage grade, test item, corresponding optional test station and test time of the test piece. The operator can edit, add, delete or search the test item data. This module provides the standard data of detection items for the subsequent scheduling module.

The inspection tasks of the current day can be imported in batches through the import function, or added one by one by adding task data. After the inspection task is completed, the inspection task report can be generated through the export function.

The basic detection project module provides the standard data of detection projects for the subsequent scheduling process, while the planned detection tasks in the detection task module are the input data of the scheduling module.

3.2. BD Monitoring Equipment Parameters

(1) Equipment status detection and preventive maintenance database

Equipment real-time operation information and maintenance management data are the main data base of equipment status detection and maintenance database. Equipment real-time operation information includes equipment output information, equipment material information, equipment maintenance records, equipment traceability quality and other information. Maintenance management data include equipment operation manual, equipment electrical/mechanical drawings, equipment maintenance instruction manual, equipment manufacturing and process entry form, etc. These data are distributed in production equipment controller, electronic data, MES and other systems. Equipment status detection database and equipment maintenance content database can be established by summarizing data from all parties.

(2) Equipment status monitoring and measurement

After setting up the equipment status detection and maintenance database, the working conditions of the equipment can be classified according to the different objectives and characteristics of the detection objects: mechanical load monitoring, motor torque monitoring, liquid level height monitoring, equipment temperature monitoring and other functions. For different detection types, establish corresponding databases, and then collect and analyze the monitoring data according to the database schedule.

(3) Equipment fault analysis based on BD

Research the equipment data obtained by the real-time online collection and monitoring system of key equipment such as CNC machining center, robot assembly unit, painting equipment, body equipment, etc., and establish the preventive maintenance parameter model of key processes and equipment. The risk of equipment production data and the corresponding trend judgment are carried out, the detection and preventive maintenance content of equipment are optimized, and the accuracy of fault prediction is improved, so as to ensure the stable operation of equipment. The equipment operation parameters, process setting parameters, quality monitoring parameters and equipment maintenance parameters are combined to reasonably optimize the equipment maintenance content and process. Based on equipment production and operation data, maintenance history data, key process data, etc., it can effectively improve the effectiveness of equipment maintenance programs and improve the ability of equipment maintenance management.

(4) Prediction and alarm of potential equipment failure

After the production equipment fluctuates from a stable operating state, the system can automatically identify the fluctuation and change of the equipment, and implement monitoring. When the change trend of the equipment state is close to the potential failure and fault, the system can automatically generate the equipment alarm, and push the equipment fault alarm to the relevant equipment management and maintenance personnel through the communication methods such as app push, e-mail, mobile phone SMS, etc.

(5) BD deep learning architecture

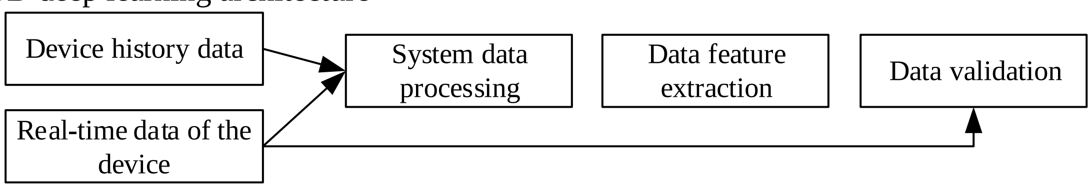

Figure 3. BD deep learning software architecture

According to the above BD modeling route, the system will continuously collect the current system data of the current equipment in real time, compare the collected data with the historical data of the equipment, analyze the data characteristic values required by the system, and use the real-time data to verify the rationality of the key characteristics.

(6) System architecture of BD analysis

The core of BD analysis technology is data processing method and system algorithm model. With the continuous increase of data acquisition points and data acquisition of production equipment, the software and hardware architecture of computing also needs to support the algorithm of BD. If distributed data storage is used, the system algorithm of data analysis will use a large amount of underlying data for clustering analysis. In terms of data structure, first analyze the structure data of equipment characteristics, that is, classify the content, attribute, unit, length and other information of the data according to the different data structures; Secondly, further analyze the classified data eigenvalues, such as the correlation between the motor current and whether the equipment is overloaded, and finally adjust and optimize the parameters. The system architecture plays a vital role in the hardware design, function definition, software design and user data of the maintenance management system. It is the underlying foundation of the maintenance management software and the main technical support of BD analysis tools and data mining algorithms.

4. Experiment Analysis

The improved hybrid genetic algorithm is used to calculate the maximum completion time of the standard case, and compared with the optimal maximum completion time of the scheduling results in other studies. Based on the optimal maximum completion time of other studies, the relative error of the results of the two methods is obtained. The results of Experiment 1 are compared as shown in Table 1.

Table 1. Comparison of the results of Experiment 1

instance	Other Studies C∗ (min)	Propose the algorithm maxC(min)	RE（%）
1(D3d1)	216	222	2.78
2(T3t0)	92	92	0
3(D1t1)	81	79	2.47
4(D2d1)	148	151	2.03
5(T2t1)	74	69	6.76
6(D1d1)	87	84	3.45

According to the data in Table 1, draw a comparison chart of the results of Experiment 1, as shown in Figure 4.

Compared with the results of other studies, the proposed algorithm provides less optimal completion time for three groups of examples and the same optimal completion time for one group. This kind of problem only includes one car. The AGV car allocation rules and the determination of the sequence of processes in the algorithm are not applied. It can be concluded that this algorithm is not aimed at this kind of problem. However, compared with other studies, the maximum completion time of at least 50% of instances has been improved, and the relative error ratio RE is not more than 7%, which proves that this algorithm is feasible for this kind of problem

The second group of standard examples consists of 10 examples. The number of test pieces included in each example varies from 6 to 18, and the number of detection stations in all instances, including the inspected area and the area to be inspected, is 10. This group of instances is one of the benchmark instances of the most typical FJSP problem with multiple AGVs so far. To minimize the maximum completion time, the improved hybrid genetic algorithm (IGATS) is used to solve these 10 examples, and the results of the improved hybrid genetic algorithm are compared with those of other algorithms. The table shows the optimal maximum completion time obtained by each algorithm, and uses the optimal maximum completion time (C) obtained by genetic algorithm as the benchmark to calculate the relative error between each algorithm and the benchmark result. The improved examples in the table are marked with an asterisk (*), where the maximum completion time (C) is in minutes. The comparison of algorithm results is shown in Table 2.

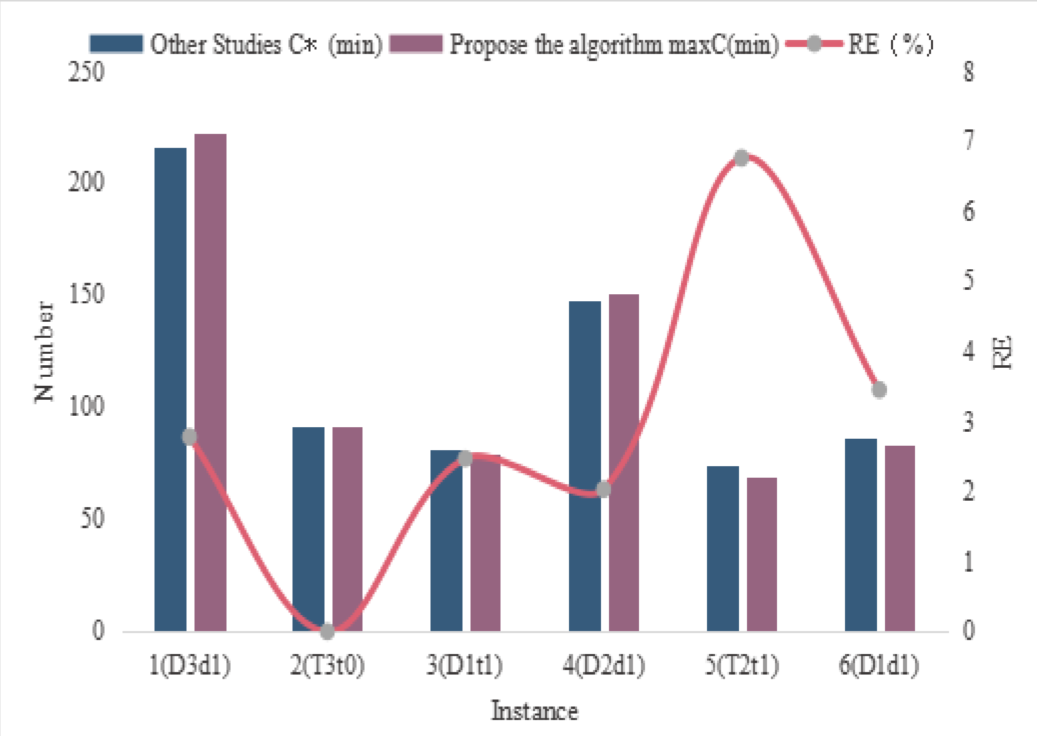

Figure 4. Comparison of the results of Experiment 1

Table 2. Comparison of algorithm results of Experiment 2

Instance	GA		TS		SB		GTSB		GATS		Proposed algorithm	
	C*	RE	C*	RE	C*	RE	C*	RE	C*	RE	Cmax	RE
1	160	0	160	0	156	2.5	146	8.8	144	10	143*	10.6
2	127	0	128	0.8	124	2.4	118	7.1	118	7.1	116*	8.7
3	164	0	162	1.2	140	14.6	124	24.4	124	24.4	118*	28.1
4	124	0	126	1.6	132	6.5	124	0	124	0	116*	6.5
5	98	0	100	2	96	2	94	4.1	94	4.1	91*	7.1
6	147	0	152	3.4	148	0.7	144	2	144	2	136*	7.5
7	132	0	132	0	132	0	122	7.6	124	7.6	121*	8.3
8	187	0	188	0.5	191	2.1	181	3.2	180	3.9	184	1.6
9	160	0	162	1.3	154	3.8	146	8.8	150	6.3	147*	8.1
10	182	0	185	1.7	185	1.7	178	2.2	178	2.2	178*	2.2

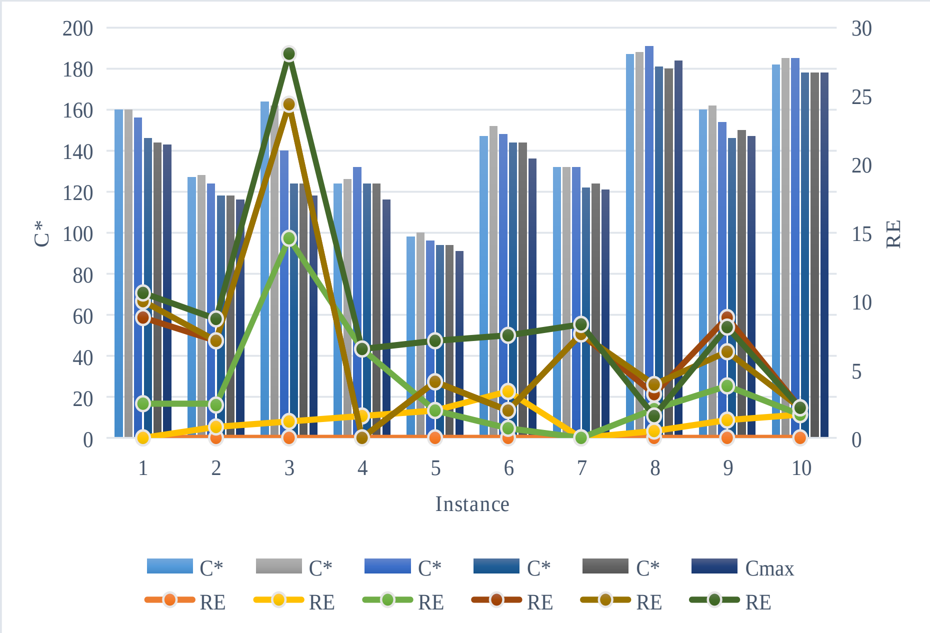

Figure 5. Comparative analysis of the algorithm results of experiment 2

Table 2 fully illustrates that compared with other algorithms, the improved hybrid genetic algorithm has achieved better scheduling results in solving FJSP problems with multiple AGVs. The comparison diagram of algorithm results in Experiment 2 is shown in Figure 5. It can be seen from Figure 5 that for most instances, the maximum completion time obtained by the improved hybrid genetic algorithm is smaller than that obtained by other algorithms. In 9 instances, the solution obtained by using the proposed algorithm is better than that obtained by other algorithms. In one instance, the solution obtained by using the proposed algorithm is lower than that of GTSB algorithm and GATS algorithm, but better than that of genetic algorithm, tabu search algorithm and conversion bottleneck algorithm. To sum up, the comparative experiments prove the effectiveness of the proposed algorithm for the workshop equipment inspection scheduling problem.

5. Conclusion

With the rapid development of BD, all industries have strengthened their contact and cooperation with BD. By establishing a BD analysis platform in line with their own development, enterprises can obtain complete data value from their historical data and real-time data through the platform, and feed it back to their future development and decision-making. Therefore, the research on BD technology and BD platform has received extensive attention. In this paper, Hadoop and Spark are used as the technical support to realize the BD platform for engineering machinery EM, and the mechanical equipment of a group is used as the test data to complete a number of storage and computing services, and a set of convenient and fast front-end services for BD visualization are realized.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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