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Big Data Analysis and Intelligent Decision Support System Construction in Mechanical Manufacturing

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Abstract: The purpose of this article is to explore the application of intelligent decision support system (DSS) in machinery manufacturing industry. Through the integration and innovation of big data processing technology, it provides efficient decision support for machinery manufacturing enterprises and promotes the intelligent transformation of the industry. In order to achieve this goal, the important role of big data in mechanical manufacturing is first expounded, and the construction process of intelligent DSS is introduced. In the system construction, the hierarchical architecture design is adopted, and key technologies such as big data analysis, machine learning and knowledge map construction are integrated, and several functional modules such as production monitoring, predictive maintenance and resource allocation optimization are designed. Then, by selecting practical application cases, the changes before and after system deployment are described. The results show that the successful application of intelligent DSS has improved the production efficiency and decision-making level of machinery manufacturing enterprises and brought tangible economic benefits to enterprises. This achievement proves the great potential of big data processing technology and intelligent DSS in machinery manufacturing industry.

Keywords: Intelligent decision support system; Mechanical manufacturing; Big data processing technology; Production efficiency; Intelligent transformation.

1. Introduction

In today's wave of Industry 4.0, the machinery manufacturing industry is facing unprecedented transformation challenges and opportunities [1]. This transformation is reflected in the innovation of production methods, but also in the intelligent upgrading of the entire industrial chain [2]. With the rapid development of Internet of Things, cloud computing, big data and other advanced technologies, machinery manufacturing enterprises began to seek to realize the automation and intelligence of production process through technical means in order to improve production efficiency, reduce operating costs and enhance market competitiveness [3]. In this context, big data analysis technology has become a key force to promote the transformation of the machinery manufacturing industry [4]. Big data analysis technology can dig deep into the massive data generated in the process of mechanical manufacturing, reveal the laws and trends behind the data through the algorithm model, and provide scientific basis for the production decision of enterprises [5]. Therefore, the application prospect of big data analysis technology in machinery manufacturing industry is broad, which is of great significance to enhance the overall competitiveness of the industry.

However, to give full play to the potential of big data analysis technology, it is very important to build an efficient and intelligent DSS [6]. Intelligent DSS can integrate all kinds of data resources inside and outside the enterprise, use advanced algorithm model for in-depth analysis, and provide timely and accurate decision-making suggestions for managers [7]. This can help enterprises to quickly respond to market changes, and also realize intelligent decision-making in complex and changeable production environment, and promote the intelligent and automatic process of machinery manufacturing industry [8]. Therefore, the construction of intelligent DSS plays an important role in the future development of machinery manufacturing industry.

The purpose of this study is to deeply discuss the construction of big data analysis and intelligent DSS in mechanical manufacturing. Through the combination of theoretical analysis and empirical research, the application path and potential of big data analysis technology in machinery manufacturing industry are clarified, and a set of feasible intelligent DSS construction scheme is put forward. The research content will focus on the selection and application of big data analysis technology, the architecture design of intelligent DSS, the integration and innovation of key technologies, and the realization and optimization of system functions.

2. Big Data Processing Technology in Mechanical Manufacturing

2.1. Overview and characteristics of big data

As a product of the information age, big data is famous for its huge data volume, rapid data flow, diverse data types and potential high value [9]. In the field of machinery manufacturing, big data includes all kinds of sensor data, equipment operation data, product quality data, etc., and also covers external information such as market trends and customer needs [10]. These data have the characteristics of large volume, many types, high speed and low value density, and need to be processed and analyzed by special technical means in order to dig out the hidden value behind them and provide support for the production decision of enterprises [11]. The application of big data technology is gradually changing the production mode and management mode of machinery manufacturing industry, and promoting the industry to develop in the direction of intelligence and refinement.

2.2. Data acquisition and preprocessing of mechanical manufacturing

In the process of mechanical manufacturing, data collection is the first step in the application of big data [12]. In order to comprehensively and accurately reflect the production situation, it is necessary to use a variety of sensors and monitoring equipment to collect all kinds of data on the production line in real time, as shown in Table 1.

Table 1. Data Collection Table for Production Line in Mechanical Manufacturing Process

Data Collection Point	Sensor/Monitoring Equipment Type	Collection Parameter	Data Unit	Collection Frequency (times/minute)
Machine Tool Spindle	Vibration Sensor	Vibration Amplitude	mm	10
Machine Tool Feed System	Displacement Sensor	Displacement	mm	5
Cutting Tool	Temperature Sensor	Temperature	℃	20
Cutting Area	Sound Sensor	Sound Pressure Level	dB	15
Workpiece Surface	Optical Sensor	Surface Roughness	μm	5
Coolant System	Flow Sensor	Flow Rate	L/min	1
Motor Current	Current Sensor	Current Value	A	10
Production Line Environment	Temperature and Humidity Sensor	Temperature/Humidity	℃/%RH	1
Material Conveyor Belt	Weight Sensor	Material Weight	kg	2
Finished Product Inspection Area	Vision Inspection System	Dimensions/Defects	-	1 (per product)

The original data often have problems such as noise, missing and abnormality, and direct analysis will affect the accuracy of the results. Therefore, after data collection, preprocessing is carried out to ensure the authenticity and reliability of the data.

2.3. Data storage and management

Traditional database systems are often difficult to meet the storage requirements of big data, so it is necessary to adopt more advanced storage technologies (distributed file system, NoSQL database). These technologies can provide enough storage space, realize fast reading, writing and efficient retrieval of data, and meet the requirements of mechanical manufacturing industry for real-time and availability of data. In order to ensure the security and privacy of data, a perfect data security mechanism is established. These include data encryption, access control, backup and recovery, etc., to ensure the security of data during storage and transmission.

3. Construction of Intelligent DSS

3.1. System architecture design

The architecture design of intelligent DSS is the basis of its successful construction. In the field of mechanical manufacturing, the system needs to be highly integrated, flexible and extensible to adapt to the ever-changing production environment and business needs. Therefore, a hierarchical architecture is adopted, including data layer, analysis layer, decision layer and application layer, as shown in Figure 1:

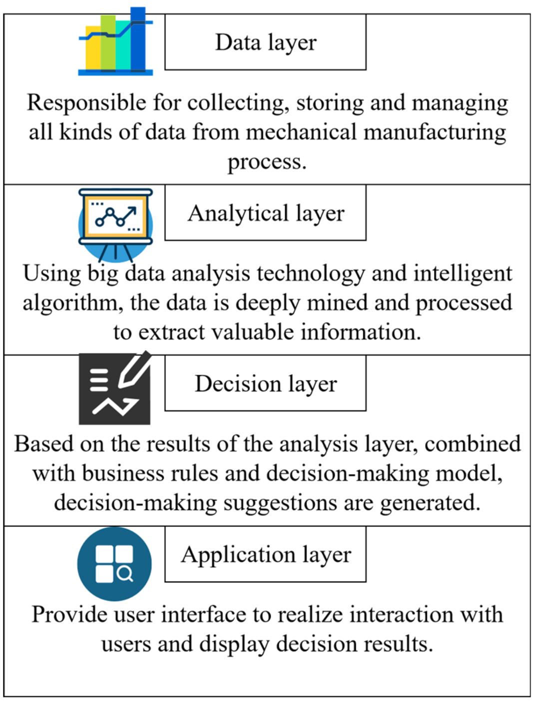

Figure 1. Hierarchical architecture

This hierarchical architecture can improve the maintainability and expansibility of the system, and at the same time ensure the security of data and the accuracy of decision-making.

3.2. Research and integration of key technologies

In the process of building intelligent DSS, the research and integration of key technologies is the core link. In this article, big data analysis technology, machine learning algorithm, knowledge map construction technology and optimization algorithm are deeply studied, and these technologies are organically integrated into the system.

As the basis of data processing, big data analysis technology plays a vital role. By introducing advanced big data analysis technology, the system realizes the rapid processing of data and accurately extracts information that is important for decision-making. This provides a solid data support for the subsequent decision-making process. The introduction of machine learning algorithm further improves the prediction ability of the system. By training and optimizing various forecasting models, we can grasp the future trend more accurately and provide forward-looking suggestions for decision makers. This data-based forecasting effectively improves the accuracy of decision-making and greatly shortens the decision-making cycle, enabling enterprises to respond to market changes more quickly.

The application of knowledge map construction technology makes the system have a deeper understanding and organization of complex knowledge system. By connecting scattered knowledge points into a network, a systematic knowledge map is formed, and the existing knowledge resources can be better utilized and integrated. It improves the intelligent level of decision-making and enables the system to deal with various complex situations more flexibly. Finally, the integration of optimization algorithms. It provides strong support for the system to solve various optimization problems. Whether it is resource allocation optimization, production scheduling optimization, or other types of optimization problems, we can find the optimal solution or approximate optimal solution by introducing advanced optimization algorithms.

3.3. System function module design

In order to meet the actual needs of machinery manufacturing enterprises, several functional modules are designed in the system. It includes production monitoring module, forecast maintenance module, resource allocation optimization module and quality control module, as shown in Table 2:

Table 2. Core Functional Modules of Intelligent DSS

Functional Module Name	Module Description
Production Monitoring Module	Real-time monitoring of key indicators during the production process, such as equipment status, production progress, output, etc., to ensure smooth production activities, promptly identify and address potential issues.
Predictive Maintenance Module	Utilizing machine learning algorithms and big data analysis techniques to predict the likelihood and timing of equipment failures, develop maintenance plans ahead of time, reduce equipment downtime, and improve equipment utilization.
Resource Allocation Optimization Module	Based on multi-dimensional information such as production demands, equipment conditions, personnel allocation, etc., employing optimization algorithms to allocate resources reasonably, enhance production efficiency, and reduce production costs.
Quality Control Module	Comprehensive monitoring of product quality during the production process, using data analysis to promptly detect quality issues, trace the source of problems, and take effective measures for improvement to ensure stable and reliable product quality.

These functional modules in Table 2 cooperate with each other to form the core part of intelligent DSS. This provides all-round support for the production decision-making of enterprises.

3.4. User interface and interaction design

User interface and interactive design are the bridge between intelligent DSS and users. This article pays attention to the friendliness and ease of use of the interface, and adopts an intuitive graphical interface and simple operation process to reduce the learning cost of users. At the same time, it also designed a wealth of interactive ways. This includes voice interaction, gesture interaction, etc. to meet the usage habits of different users. In the interface layout, the system follows the principle of clear information and convenient operation, and puts important information and functions in a conspicuous position for users to find and use quickly. The system also provides personalized setting options, allowing users to customize the interface style and functional layout according to their own needs.

4. System Implementation and Case Analysis

4.1. System implementation strategy

System implementation is the key step of intelligent DSS from theory to practice. This article adopts a phased and step-by-step implementation strategy to ensure the smooth transition and effective application of the system. First of all, communicate with enterprises in depth, make clear their actual needs and expectations, and make detailed implementation plans. Then, install and configure the system to ensure that all functional modules can run normally. Then, organize enterprise employees to carry out systematic training to improve their understanding and ability to use the system. Finally, gradually put the system into the actual production environment, through real-time monitoring and feedback, timely adjustment and optimization, to ensure that the system can provide stable support for enterprise production decisions.

4.2. Case study

Taking a well-known machinery manufacturing enterprise as an example, the enterprise is faced with problems such as low production efficiency, high equipment maintenance cost and insufficient decision-making basis in the production process. In order to improve this situation, intelligent DSS is deployed. After the system is deployed, enterprises can accurately grasp the production situation and find and solve the production bottleneck in time by collecting all kinds of data on the production line in real time and using big data analysis technology for in-depth mining. The effective application of predictive maintenance module greatly reduces the equipment failure rate and the maintenance cost. The optimized decision-making suggestions provided by the system, such as resource allocation scheme and production plan adjustment, have brought remarkable economic benefits to the enterprise. The specific display is shown in Table 3:

Table 3. Statistics Table of Application Effects of Intelligent DSSs in Machinery Manufacturing Enterprises

Indicator	Before System Deployment	After System Deployment	Improvement Rate
Production Efficiency (Increase Percentage)	Baseline (100%)	120%	+20%
Equipment Maintenance Cost (Reduction Percentage)	Baseline (100%)	85%	-15%
Decision-Making Time (Reduction Ratio)	Average Time: 5 Days	Average Time: 2 Days	Reduced to 40% of Original

Before the system deployment, the production efficiency of the enterprise was 100% of the benchmark value, and after the system deployment, the production efficiency increased to 120%, that is, increased by 20%.

Before system deployment, the equipment maintenance cost was 100% of the benchmark value, and after system deployment, the maintenance cost was reduced to 85%, that is, it was reduced by 15%. This reflects the effective role of predictive maintenance module in reducing equipment failure rate and maintenance cost.

The average decision-making time before system deployment is 5 days, and it is shortened to 2 days after system deployment, that is, the decision-making time is shortened to 40%. This reflects the advantages of intelligent DSS in accelerating the decision-making process and improving the decision-making efficiency.

4.3. Performance assessment and improvement suggestions

In order to comprehensively assess the performance of intelligent DSS, a variety of quantitative indicators are adopted, including data processing speed, decision accuracy and user satisfaction. The test results are shown in Table 4:

Table 4. Performance Assessment Results of Intelligent DSS

Assessment Metric	Specific Value/Description
Data Processing Speed	Average Processing Time: < 1 second (for large datasets)
Decision Accuracy	Accuracy Rate: 92% (based on historical data validation)
User Satisfaction (Overall)	Satisfaction Score: 4.7/5 (based on employee survey)
User Satisfaction (Usability)	Usability Score: 4.6/5
User Satisfaction (Effectiveness)	Effectiveness Score: 4.8/5
User Satisfaction (Support)	Support Score: 4.9/5 (including technical support and training)

After the actual test, the intelligent DSS has shown excellent performance in processing massive data, and the average processing time is less than 1 second, which significantly improves the data processing efficiency. The decision accuracy of the system is as high as 92%. The verification based on historical data shows that the system can make highly accurate decision suggestions. In terms of user satisfaction, through the survey of employees, the overall satisfaction score is 4.7/5, and the scores of usability, effectiveness and support are also close to or above 4.8/5. This shows that the employees of the enterprise positively assess the experience and effect of the system.

However, during the assessment process, some improvements were also found. For example, although the user interface of the system is friendly, some details can be further optimized to improve the efficiency of users. With the continuous development of enterprise business, the system also needs to be updated and iterated to meet the new requirements. Therefore, it is suggested to continuously optimize the system in the future. This includes strengthening the interactive design of user interface, introducing more advanced algorithms and technologies, and perfecting the functional modules of the system. In order to ensure that the system can always provide efficient and accurate decision support for enterprises.

5. Conclusions

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