ABNORMAL DATA ACQUISITION SYSTEM OF MECHANICAL OPERATION BASED ON BLOCK CHAIN TECHNOLOGY

by

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In order to solve the problems of information sharing, tampering and leaking in mechanical operation data acquisition, an abnormal data acquisition system for mechanical operation based on block chain technology was designed. The system takes Beihang Chain as the prototype and designs the overall architecture of the system. Data acquisition module uses data acquisition card, CPU, programmable logic device, A/D conversion chip and other equipment to collect and process abnormal data in mechanical operation. The alarm module divides the abnormal data collected by the data acquisition module into five levels: P1-P5. After the implementation of the alarm module, the abnormal information and alarm information in the process of mechanical operation are transmitted to the abnormal data management module for storage. The system adopts the method of mechanical operation anomaly data acquisition based on sparse sampling, and adopts hierarchical clustering method to establish the data acquisition tree of mechanical operation anomaly. The block chain technology is used to design the process of storing and monitoring abnormal data of mechanical operation. The experimental results show that the system has high accuracy of fitting curve for abnormal data acquisition, low real-time energy consumption, and the minimum energy consumption is only 0.01/10-3 J.

Key words: *block chain technology, mechanical operation, abnormal data, acquisition system, Beihang Chain, sparse sampling*

Introduction

In order to avoid unnecessary losses, it is necessary to monitor mechanical operation data in real time and collect abnormal data of mechanical operation. By comprehensively analyzing these abnormal data, repairmen can judge or predict mechanical failure, so as to reduce the mechanical failure rate and prolong mechanical life [1, 2]. The designers can find the shortcomings of mechanical structure and develop better products [3-5].

There are many ways to collect abnormal data of mechanical operation, but all of them have some defects. For example, Kuang and Wang [6] designed a mechanical operation abnormal data acquisition system based on embedded technology. Because of the limitation of embedded technology, CAN node controller can only deal with some real-time information, but the information is easy to be tampered with. Wu *et al.* [7] designs the abnormal data acquisition system of mechanical operation based on compressed sensing theory. In this system, the

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abnormal data information of mechanical operation cannot be shared and the storage space is limited, so the information of mechanical operation can only be saved in a short time. Nikitaev *et al.* [8] designs the abnormal data acquisition system based on adaptive intelligent technology. The system cannot guarantee the privacy of abnormal data information of mechanical operation.

The IBM also regards block chain technology as TCP/IP in the era of Internet of Things, which will become the key technology to solve the core problems about information security, data storage and interactive processing in the Internet of Things [9-11]. On this basis, an abnormal data acquisition system for mechanical operation based on block chain technology is designed, which can effectively solve the difficult position of diversification development of mechanical operation information.

Methods

Block chain development technology-Beihang Chain

Beihang Chain is a license chain jointly developed by Beijing University of Aeronautics and Astronautics and Peking University. Beihang Chain introduced node credit system and adopted parallel byzantine fault tolerance (CBFT), which accelerated the speed of information processing. Double-chain structure including account block chain (ABC) and transaction block chain (TBC) is adopted to improve scalability and throughput [12], and reduce the risk of delay and privacy leakage.

Beihang Chain architecture includes five layers: application layer, code layer on chain, interface layer, block chain service layer, and storage layer, as shown in fig. 1. The application layer deploys applications. The code layer on the chain provides service that is connected with the contract. The interface layer provides external and internal API interfaces. The block chain service layer deploys the block double-chain system. The storage layer includes operating system and database services.

Design of data acquisition module

Taking DSP as CPU, the data acquisition module uses data acquisition card, programmable logic device (CPID), A/D conversion chip, PCI interface chip, memory chip and other devices to realize the acquisition and processing of various signals in the process of abnormal data acquisition of mechanical operation.

The running data of mechanism are mainly vibration parameters, including amplitude, vibration frequency, phase, speed, axis displacement, temperature, pressure and flow rate. The data acquisition card uses DSP chip TMS320LF240 as the control and data analysis center of the data acquisition card, which realizes the process control for main program, the digital filtering of collected data and the analysis of abnormal data.

Design of alarm module

The main functions of the alarm module of abnormal data acquisition: according to the relevant standards of abnormal data during mechanical operation given by the mechanical manufacturer, the hazard level and possible loss rate of the abnormal data of mechanical operation collected and analyzed by the system data acquisition module are alerted. According to the abnormal degree of data, the system divides the abnormal data during mechanical operation into five levels, which are expressed by P1-P5, where, P1: no abnormality, P2: mild abnormality, P3: moderate abnormality, P4: severe abnormality, P5: extreme abnormality. The working principle of alarm module is shown in fig. 2.

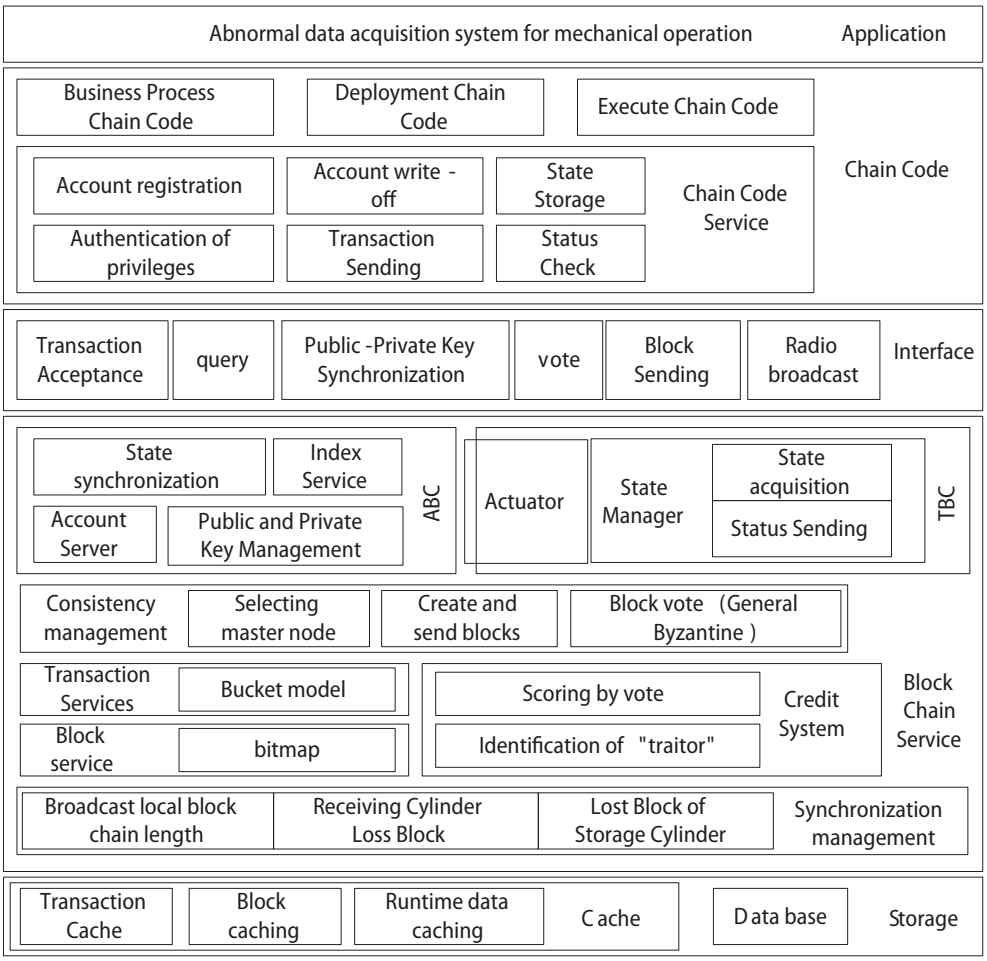

Figure 1. North airlines chain structure

Architecture design of abnormal data management module

The framework of abnormal data management module of mechanical operation is divided into four layers. From top to bottom, they contain application layer, code layer, block chain service layer and storage layer.

- Application layer: it maps out visual programs, interacts with users, and sends user's operation request and private key to the code layer on the chain for further processing.
- The code layer on the chain: decrypt and verify the private key sent by the user, and judge whether the request is valid according to the user's rights. If valid, proceed to the next step according to the mode of operation, otherwise access is denied.

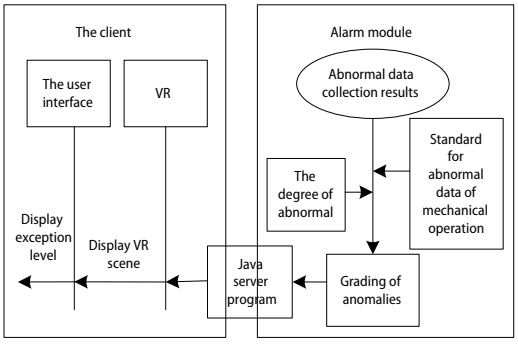

Figure 2. Working principle of alarm module

– Block chain service layer: according to the feedback from the database, the need to delete blocks is judged. After successful operation, the database and Merkle tree of all nodes in the whole network will be synchronized. If the operation fails, the block will be deleted.
– Storage layer: it is used for storing user data and responding to user's operation request.

Software design

Abnormal data acquisition method of mechanical operation based on sparse sampling

The hierarchical clustering method is used to build the data acquisition tree of mechanical operation. The data sensors in each acquisition unit of mechanical operation are regarded as a class. We can suppose that there are M data sensors in the system of abnormal data acquisition of mechanical operation, which are divided into two categories, a and b. According to N mechanical units, they are divided into n categories. These categories are hierarchically aggregated one by one through the distance relationship. The formula is:

$$D_{m,n} = \sum_{m=1,n=1}^{a-x,b-y} \frac{d_{ab}}{x \times y} \tag{1}$$

where m denotes the number of nodes in the acquisition unit of mechanical operation, $m_n \in M$ – the category of hierarchical aggregation of collection data during mechanical operation, $n_n \in N$, d_{ab} – the distance between m_n and n_n, $D_{m,n}$ – the distance between categories of collection data during mechanical operation, x – the node obtained by data calculation, and y – the variance of distance between operation data.

After using eq. (1) to construct the data acquisition tree of mechanical operation, the distribution of data in the whole process of mechanical operation is known. Next, the data of mechanical operation need to be grouped and the number of nodes in each group can be calculated by:

$$x = \sum\nolimits_{i,j} \frac{d_{ij}}{d_{ab}(i,j)} \tag{2}$$

where $d_{ab}(i, j)$ denotes the distance between data in class a and class b. After calculating the node of mechanical operation data, the distance variance between the two groups of operation data is calculated:

$$y = \sum_{m,n \in y} \frac{d_{mn}}{d_{ab}(m,\mathrm{n})} \tag{3}$$

After constructing the data acquisition tree and completing the data grouping during the mechanical operation, the abnormal data of mechanical operation are collected, which are marked by the following formula:

$$W = \begin{bmatrix} \dfrac{\delta x'}{\delta z'} \dfrac{\delta z'}{\delta x'} \dfrac{\delta x'}{\delta y'} \\ \dfrac{\delta y'}{\delta z'} \dfrac{\delta x'}{\delta y'} \dfrac{\delta z'}{\delta x'} \end{bmatrix}, \quad Q = \begin{bmatrix} x' - \chi \\ y' - \eta \end{bmatrix} \tag{4}$$

where W denotes time parameter, Q – the abnormal data node of mechanical operation. Respectively, x', y' and z' denote collected abnormal data. According to the formula, the abnormal data acquisition during the mechanical operation can be completed.

Procedure for storing and supervising abnormal data of mechanical operation

The transmission of abnormal data of mechanical operation still adopts the traditional GPRS data transmission, only adding the control logic of encrypting and storing the data. Therefore, only adding the program code with block chain technology to the original electrical control program can complete the data storage.

The abnormal data of mechanical operation are collected and stored in block chain. The flow chart is shown in fig. 3.

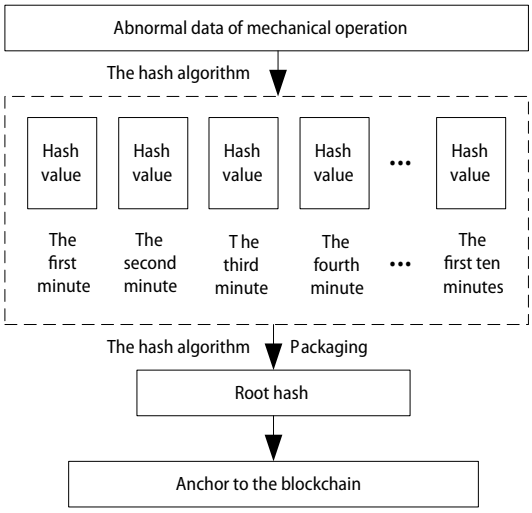

Figure 3. The process of storing abnormal data of mechanical operation to block chain

Hash algorithm generates a fixed binary value from unlimited data. This fixed value is a hash value. The anchor is the process of writing Merkel root (root hash value) into the block chain. From the beginning, the machine saves the abnormal running data of the current period within one minute every one minute and generates the hash value by hash algorithm at the same time. Ten hash values generated in ten minutes are written into the text. This text is hashed again to generate a unique hash value, which is called root hash. Because the block chain generates a new block every ten minutes, the time is matched as the root hash value generated by the abnormal data of mechanical operation within 10 minutes, which is written into the block chain, so that it can be preserved permanently and tamperproof.

Experiment

In order to verify the comprehensive performance of the abnormal data acquisition system of mechanical operation based on block chain technology, this paper takes a machine as an experimental object and uses the simulation tool of MATLAB to compare the proposed system, the abnormal data acquisition system of mechanical operation based on compressed sensing and the abnormal data acquisition system of mechanical operation based on adaptive intelligence. The data of the following simulations is collected by the No. 5 node in data acquisition system of experimental object deployed by the Intel Berkeley research group in a certain time domain. The Inter Core i7-4710MQ CPU at 2.50 GHz processor is adopted.

Simulation of abnormal data acquisition during mechanical operation

In the previous simulation environment, three abnormal data acquisition systems are used to simulate. Figures 4(a) and 4(b) are all the comparisons between the sampling results of abnormal data of same experimental objects and the original data. The number of abnormal data sampling results and the original data sampling points are 50.

According to the comparison of fig. 4, it can be seen that all abnormal data sampling points in fig. 4(a) are uniformly distributed on the original abnormal data curve. In fig. 4(b), all the sampling points of abnormal data are sparsely distributed in the stage of smoother

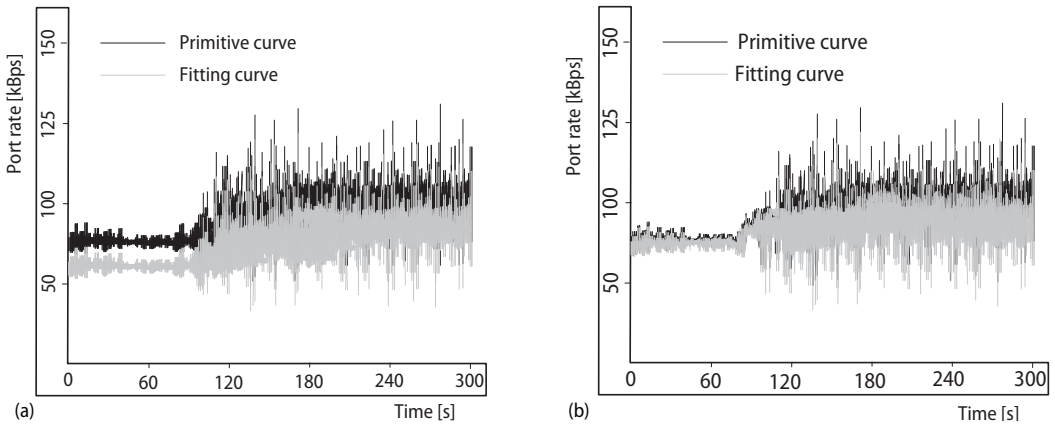

Figure 4. Comparison of abnormal data acquisition results of different acquisition systems; (a) smulation results of acquisition system based on compressed sensing and (b) system simulation results in this paper

data change. In the stage of drastic changes of abnormal data, the sampling points are denser. Therefore, the proposed system has good performance of anomaly data acquisition.

Comparison of system performance

In order to verify the performance of system, three abnormal data acquisition systems of mechanical operation are compared in practice form various aspects. The comparison results are shown in tab. 1.

Table 1. Performance comparison of different detection systems

	The system in this paper	A data acquisition system based on compressive sensing	Acquisition system based on adaptive intelligence
Construction time	1-2.5 days	3-5 days	2-6 days
Cost (10000)	About 16000 Yuan	About 28000 Yuan	About 42000 Yuan
Client	User interface display effect is better	User interface display effect is ordinary	User interface display effect is better
Server	Efficient	Poor efficiency	Medium efficiency
Operational efficiency (%)	71.17%	46.24%	54.66%

According to tab. 1, we can see that compared with the data acquisition system based on compressed sensing and the data acquisition system based on adaptive intelligence, the proposed system in this paper has lower construction time and cost. The effect of client display of the proposed system is better. The proposed system adopts block chain technology, which has the advantages of decentralization, information without tampering, anonymity and big storage space. Experimental results show that the system has excellent practicability and good interface display effect, so that it can be widely applied in the field of abnormal data acquisition of mechanical operation.

Comparison of system energy consumption

In order to test the real-time energy consumption of proposed system, three abnormal data acquisition systems are used to collect the abnormal data of experimental objects, and

then the real-time energy consumption of the three systems is compared. The results are shown in fig. 5.

From the analysis of fig. 5, it can be seen that the real-time energy consumption range of the acquisition system based on adaptive intelligence is between 0.020[10^{-3}J] and 0.047[10^{-3}J], and the real-time energy consumption range of the acquisition system based on compressed sensing is between 0.015[10^{-3}J] and 0.052[10^{-3}J]. The average energy consumption of the acquisition system based on adaptive intelligence is 0.036[10^{-3}J], the average energy consumption of the acquisition system based on compressed sensing is 0.039[10^{-3}J], and the real-time energy consumption range of the system is 0.01[10^{-3}J]~0.026[10^{-3}J]. It shows that the real-time energy consumption of the system is low when collecting abnormal data of mechanical operation.

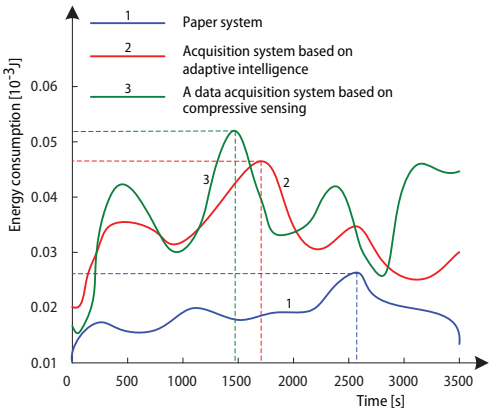

Figure 5. Comparison of real-time energy consumption curves for different detection systems

Discussions

The advantage of this system is mainly due to the block chain technology. Through the analysis of the concept of block chain, the characteristics of block chain are summarized into two aspects.

- Decentralization and untrustworthy: Block chain is an end-to-end network that consists of many nodes. There is no centralized equipment and management organization. The abnormal data exchange between nodes is verified by digital signature technology without mutual trust. As long as it follows the established rules, the node cannot deceive each other.
- Transparent transaction and anonymity of both parties: the operation rules of block chain are open and transparent, and all abnormal data information of mechanical operation is also open, so every transaction is visible to all nodes. Because the trust between nodes is removed, there is no need for public identity between nodes, and each node is anonymous.

Conclusion

Taking Beihang chain as an example, the abnormal data acquisition system and data acquisition module of mechanical operation based on block chain technology are designed. The experimental results show that the system has the advantages of high accuracy and low energy consumption in abnormal data acquisition and fitting curve. Compared with other two systems, the energy consumption of this system is reduced by 0.019[10^{-3}J] and 0.022[10^{-3}J], respectively.

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