Research on Remote Monitoring and Fault Diagnosis System for Coal Mine Electromechanical Equipment

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Abstract. This article proposes an architecture of equipment remote monitoring and fault diagnosis system in view of the increasingly complex business logic and functional requirements of the current coal mine electromechanical equipment remote monitoring and fault diagnosis system. We established a loosely coupled Web service system by abstracting and dividing the business logic and functional requirements of the remote monitoring and fault diagnosis system at different levels and different granularities. At the same time, we use the fault diagnosis model of multi-scale residual network and attention mechanism algorithm to verify the effectiveness of the fault diagnosis system.

Keywords: Coal mine electromechanical equipment, fault diagnosis model, multi-scale residual network, attention mechanism algorithm.

1. Introduction

Large-scale coal mine electromechanical equipment is a key equipment in many industries in the national economy. Once a failure occurs, it will bring huge economic losses to the factory and the country. Therefore, it is particularly important to monitor and diagnose the state of large-scale electromechanical equipment. However, due to the limitation of signal transmission distance and real-time requirements in the industrial field, traditional monitoring and diagnosis systems, such as manual offline monitoring and diagnosis methods, stand-alone online monitoring and diagnosis systems, and centralized monitoring and diagnosis systems, are difficult to achieve Remote monitoring and fault diagnosis of equipment in remote locations [1]. As a result, advanced theories, technologies, and data information cannot be shared, resulting in a waste of knowledge resources. With the development of computer network technology, the research and application of network-based remote monitoring and fault diagnosis systems have developed rapidly.

The research on equipment fault diagnosis technology first started in the United States and has developed to the present. In terms of models, it has roughly gone through three stages:

1) Single-machine online fault monitoring and diagnosis mode Install a set of fault monitoring and diagnosis system for each device. This method has good real-time performance and high reliability, but it has poor economy and it is difficult to share information between various monitoring and
diagnosis systems. 2) The centralized online fault monitoring and diagnosis method overcomes the shortcomings of the stand-alone method such as poor economy and difficult information sharing. However, this method is prone to distortion and interference due to the long signal cable. Due to the increase in the number of data acquisition channels and storage capacity, the real-time performance of monitoring is poor, and due to geographical restrictions, it is difficult to carry out remote diagnosis. 3) The remote distributed online monitoring and fault diagnosis method combines the advantages of the single machine online working condition monitoring and fault diagnosis and the centralized online working condition monitoring and fault diagnosis method [2]. In this way, each unit is equipped with a set of data acquisition monitoring system, and multiple data acquisition monitoring systems share a set of diagnostic system. In this way, it not only guarantees the real-time monitoring (even during diagnosis, it can guarantee uninterrupted monitoring), but also realizes the sharing of information, and at the same time saves the cost of the monitoring and diagnosis system.

2. Design of state monitoring and fault diagnosis system for electromechanical equipment

2.1. Overall structure design

The schematic diagram of the structure of the network-based electromechanical equipment remote monitoring and fault diagnosis system developed on the LabVIEW platform is shown in Figure 1.

![Figure 1. Schematic diagram of the structure of the remote monitoring and fault diagnosis system for electromechanical equipment](image)

The operating status of the field unit equipment is connected through the front-end intelligent data acquisition MCU and the GPRS wireless transmission module, and is transmitted through the GPRS network. The monitoring centre communication module obtains the original data of the operating status of the field equipment based on the TCP/IP protocol communication module, and the original data is stored separately in the historical database and real-time database of the database server in the monitoring centre. These data reflect the past history and current state of the unit equipment, as well as the future development trend, and are an important source of information for fault diagnosis.

After the monitoring and diagnosis centre has judged the monitoring and diagnosis objects, it will make corresponding instructions on the current situation, which can be transmitted back to the data
terminal side for execution, or sent to management and maintenance personnel via SMS, which provides a basis for the implementation of fault prevention and maintenance measures [3]. In this way, real-time monitoring and real-time diagnosis of the operating status of on-site equipment are realized, and data is exchanged between maintenance personnel, expert control centres and equipment, so that technicians and managers can get every monitoring point no matter where they are. Data, and can respond in a timely manner.

2.2. Functional design
The remote monitoring system has two main functions: On the one hand, it is responsible for processing, extracting and analysing the signal data acquired by the on-site front-end acquisition system and transmitting it to the monitoring client in real time. The monitoring client uses various charts to display the operating status of the equipment in real time. On the other hand, it stores these signal data in the database, provides data query functions, and displays the historical operating status of the equipment. Therefore, the remote monitoring system can be abstracted into the following aspects: 1) Signal acquisition, that is, the front-end acquisition system acquires various monitoring signals in real time. 2) Signal processing and analysis, including signal noise reduction, calculation of characteristic values, alarm status judgment and spectrum analysis, etc. 3) The display of the signal, the signal is displayed in a variety of ways such as waveform curve, bar graph and data table. 4) The storage of the signal, the classification of the signal is stored in the database for query. 5) Inquiry of signals usually includes inquiries about signal details at a certain point in time and inquiries about the trend of changes in a certain period of time.

The fault diagnosis system mainly uses real-time or historical data to diagnose the operating conditions of the equipment through various diagnostic methods [4]. At the same time, the system can analyse the operating status signal of the equipment according to the user's request and give the diagnosis result. In interactive diagnosis, users can also submit more advanced diagnosis requests (such as expert diagnosis) to the remote diagnosis centre, or submit their own diagnosis results to the diagnosis centre as a typical diagnosis case. Figure 2 shows the remote state monitoring and fault diagnosis system functions of coal mine electromechanical equipment.

![Figure 2. Remote state monitoring and fault diagnosis system functions of coal mine electromechanical equipment](image)

2.3. Module design
2.3.1. **Smart front end.** Each intelligent front end is a networked VXI/PXI equipment monitoring unit, which adopts an event-driven data acquisition strategy to complete the self-adaptive and synchronous acquisition of vibration, speed, and process signals during the entire process of steady-state, speed-up and down-speed operation of the local unit, and feature extraction, Alarm judgment and online transmission and storage tasks.

2.3.2. **Remote monitoring workstations within the enterprise.** The remote monitoring workstations developed based on the LabVIEW graphical development platform can be flexibly distributed on the unit site and other places within the enterprise to realize digital and graphical remote monitoring of the working conditions of multiple units.

2.3.3. **Enterprise internal analysis and diagnosis workstation.** The data collected and stored in the database will be analyzed to realize the routine diagnosis tasks within the enterprise. In addition to providing classic analysis and diagnosis technology, it also includes medium and long-term trend analysis and prediction of large-scale unit operation, intelligent diagnosis of common faults of large-scale unit, and online monitoring and diagnosis of shaft stability of high-speed rotating machinery. The above modules are based on LabVIEW. Platform development, easy to expand and upgrade instantly.

2.3.4. **Remote diagnosis center.** Accept the enterprise's request for difficult problems, provide effective monitoring and diagnosis tools and organize expert consultations, analyze the data of difficult problems, and feedback the diagnosis results to the enterprise.

2.3.5. **Database server.** divided into central database and enterprise-level database. The central database stores and manages the monitoring data files of the networked enterprise monitoring system. The enterprise-level database server saves complete data records of the equipment status, and it provides the current and historical data needed for the internal analysis and diagnosis workstations of the enterprise.

3. **Fault diagnosis model of multi-scale residual network and attention mechanism algorithm**

3.1. **Residual network**

The residual module does not fit the direct mapping of multiple network layer stacks, but fits the residual mapping. Assuming that the input of a residual module is \(X\), and the direct mapping is expressed as \(H(x)\), the residual mapping can be expressed as \(F(x) = H(x) - x\), and the corresponding direct mapping can be redefined as \(H(x) = F(x) + x\). It can be seen from the above expression that the residual mapping of network fitting is much easier than the direct mapping of fitting. \(H(x) = F(x) + x\) can be realized by means of quick connection, that is, the input of the upper layer is connected by crossing one or more layers of networks [5]. The shortcut connection only performs identity mapping and adds its output to the output of the residual block. The structure of a residual module is shown in Figure 5-1, and its calculation process can be expressed as:

\[
y = F(x, \{W_i\}) + x
\]  

(1)

Among them, \(x\) and \(y\) represent the input and output of the residual module, respectively, and \(F(x, \{W_i\})\) represents the residual mapping to be learned [6]. It can be seen that the shortcut connection method of identity mapping does not increase additional parameters and calculations.

3.2. **Attention mechanism**

The Squeeze and Excitation Network (SENet) introduces the dynamic and non-linear interdependence
between the explicit modeling feature channels of the Squeeze and Excitation module, thereby simplifying the learning process and improving the quality of output features and the expressive ability of the network [7]. The SE module can realize the arithmetic unit that maps the input feature map $X \in R^{H \times W \times C}$ to the feature map $U \in R^{H \times W \times C}$, $F_{tr}$ represents the convolution operation, $V = [v_1, v_2, \cdots, v_C]$ represents the feature parameter in the convolution kernel, and the output is expressed as $U = [u_1, u_2, \cdots, u_C]$, then the calculation of the C convolution kernel output $u_c$. The process can be expressed as:

$$u_c = v_c \ast X = \sum_{s=1}^{C} v_c^s \ast X^s$$  \hspace{1cm} (2)

3.2.1 Extrusion operation. For a given feature map $U^{H \times W \times C}$, while keeping the number of feature channels unchanged, according to the spatial dimension $H \times W$, each feature map is compressed into a set of real value of feature channel weights with global information. Suppose the set of statistics is, then the calculation process of the C feature of can be expressed as:

$$z_c = F_{sq}(u_c) = \frac{1}{H \times W} \sum_{i=1}^{H} \sum_{j=1}^{W} u_c(i, j)$$ \hspace{1cm} (3)

After the feature map $U^{H \times W \times C}$ is squeezed and transformed, a set of local descriptors that can characterize its global information can be obtained.

3.2.2 Incentive operation. In order to meet the above conditions, in the excitation operation, a simple S-type gating mechanism using the ReLU function as the activation function is implemented. The gating mechanism can be expressed as:

$$s = F_{ex}(z,W) = \sigma(g(z,W)) = \sigma(W_1 \delta(W_2 \cdot z))$$ \hspace{1cm} (4)

Among them, $W_1 \in R^{C_{tr} \times C}$ and $W_2 \in R^{C \times C_{tr}}$ two parameters are used to generate a weight for each characteristic channel, so as to realize the description of the correlation between different characteristic channels. $\delta(\cdot)$ represents the ReLU activation function.

4. System Inspection
The demonstration system mainly provides the client of the Web-based remote monitoring system. Here, the real-time waveform monitoring of vibration signals (Figure 3) and the characteristic value bar graph monitoring are taken as examples to show the effect of the monitoring system. It can be seen that, on the one hand, it has successfully realized the monitoring interface and operation completely based on the Web mode [8]. On the other hand, the design and implementation of the monitoring interface is very simple and easy because it is separated from the client's data and business, so it will be very convenient in the future. To design a richer and more complete monitoring interface for the actual application system.
5. Conclusion
This paper proposes a remote monitoring and fault system architecture. The system first abstracted and divided the business logic and functional requirements of the remote monitoring and fault diagnosis system at different levels and different granularities, and established a loosely coupled Web service system. Then the multi-scale residual network and the attention mechanism algorithm model are given, which makes the functional modules more reusable and easier to expand the system. This paper realizes the effective integration of decentralized and heterogeneous monitoring and diagnosis system resources.

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