SIGNAL PROCESSING AND THERMAL PERFORMANCE ANALYSIS OF MOTOR HEAT RECOVERY SYSTEM

by

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In order to realize the condition monitoring of the motor "anytime, anywhere", improve the detection accuracy and shorten the detection time, the author proposes a fault signal processing and diagnosis system for the motor heat recovery system based on the IoT. That is, based on the IoT technology, a mobile terminal oriented motor remote monitoring and fault diagnosis system, the sensing layer of the system collects real-time motor operation status data, and the transmission layer realizes data transmission, cloud storage and response to data requests from the application layer, finally, at the mobile end, the motor running status and diagnosis results are displayed through charts and text, so as to realize remote monitoring and fault diagnosis of the motor. The experimental results show that the accuracy of fault diagnosis test of GA-SVM in mobile terminal is more than 90%, and the running time is less than 30 ms, and the running time is very short. It proves that the mobile terminal uses the fault detection method based on GA-SVM model with high accuracy and short detection time, that is, the fault signal processing and diagnosis accuracy of the motor heat recovery system of the IoT is high and the detection time is short.

Key words*: IoT, electric machinery, heat recovery system, fault signal, diagnostic processing*

Introduction

In the early days, people mainly relied on experienced technical workers to diagnose the faults of machinery and equipment driven by the motor by seeing, hearing and touching the machinery and instruments on the site. This not only required high technical experience of workers, but also generally the workers with motor faults could not be present on the site in time, which often caused irregular losses to enterprises, In this way, only the field workers can measure the machine simply through simple measuring instruments, but it is not easy to measure some complex machine data, and it requires a lot of human and material resources, which seriously affects the normal production of the enterprise. With the development of science and technology, measurement technology and sensor technology have made further development by using simple sensor to measure data. About the late 20th century, it basically appeared to use microcomputer equipment combined with sensor elements to measure machine data more accurately, but the analysis of data still needs the help of experts engaged in relevant work. Although the accuracy of machine monitoring has been improved to a certain extent, and this

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technology has also been applied to various motor fault monitoring systems, the technology is more complex and the cost is higher [1].

Networking technology is a new network transmission technology based on computers. The essence is to realize communication between different objects according to the inherent protocol, and realize the IoT through electromagnetic technology, the intelligent control is realized according to the information between objects, so that objects can be endowed with the ability to receive and process information, and can automatically complete the signal transmission, action processing, automatic management and control of preset programs. It can be widely used in the field of intelligent life: for example, in the smart home industry, it can automatically realize the intelligent life of lights and household appliances in family life. In the field of industrial production: the machine equipment can actively report its own operating data and status, which is mainly the self processing function in dangerous situations. In the military field, it can realize the intelligent active monitoring and alarm function. Promote modern industrial production and personal life to be more intelligent, safe and refined [2].

Electric motor is the key power device of important equipment such as energy, ship military industry, and its safe operation is of great importance. How to carry out real-time state monitoring and fault diagnosis of motor has been widely concerned. With the development of IoT technology and 5G technology, mobile devices have evolved into a convenient and flexible tool, which has become a necessary carry on item for everyone. At present, the configuration of mobile devices is getting higher and higher, and the computing power is getting stronger and stronger. Obviously, it is feasible and urgent to develop a remote motor monitoring and fault diagnosis system for mobile terminals, fully tap the potential of the IoT and 5G technology, and realize the *anytime, anywhere* condition monitoring and fault diagnosis of motors [3].

Therefore, in order to solve this problem, the author designed a remote motor monitoring and fault diagnosis system for mobile terminals based on IoT technology, the sensing layer of the system collects the state data of motor operation in real time, and the transmission layer realizes data transmission, cloud storage and response to data requests from the application layer, finally, at the mobile end, the motor running status and diagnosis results are displayed through charts and text, so as to realize remote monitoring and fault diagnosis of the motor.

Literature review

Research on motor fault diagnosis technology, designed a multi-channel motor parameter acquisition system based on ARM data, which sent the real-time data of all sensors collected to the host computer, the TMS320F2503 series chips of ARM company were used as the controller. In this research, a data transmission port is used to collect and transmit multi-channel parameter data of multiple motor parameters, the system method is flexible, reliable and low cost. Bai *et al*. [4] put forward an embedded monitoring system technology with ARM as the processor to be applied to the motor monitoring system, this method uses the embedded operating system to realize online monitoring of different parameters such as voltage, current, temperature*, etc.* of the motor. To a large extent, the accuracy and real-time performance of the monitoring system are improved, but the judgment of the fault still requires experienced technicians to analyze the collected data displayed on the site. Wu *et al*. [5] designed a hardware system detection based on the IoT chip CC2430 wireless sensor protocol, which can monitor the running state data of the motor. The system also realizes data acquisition and transmission through wireless mode, but the selection of sensor hardware and wireless routing is not optimal. Wencai *et al*. [6] designed a set of remote monitoring system for motor running state based on ZigBee chip and a fault analysis management system based on PSO algorithm, which was applied to the AC motor of coal mine drilling rig. It can realize synchronous real-time collection, remote transmission and data fault processing of the operating state parameters of multiple mining motors. Not only the in-service staff can monitor the motor operating data and working conditions in real time, but also the remote high tech talents or managers can remotely and timely master the working state of each drilling motor, according to the algorithm, the motor fault is analyzed accurately. Zhuo *et al*. [7] proposed a large motor remote monitoring technology based on the Android platform, which presents the running state of the motor on the smart phone through the IoT, helping users to grasp the running state of the motor at any time and anywhere, realizing remote monitoring of large motors, and laying a foundation for fault diagnosis of large motors.

Based on the current research, the author proposes a fault signal processing and diagnosis system for motor heat recovery system based on the IoT. Based on the IoT technology, the mobile terminal oriented motor remote monitoring and fault diagnosis system, the sensing layer of the system collects real-time motor operation status data, and the transmission layer realizes data transmission, cloud storage and response to data requests from the application layer, finally, at the mobile end, the motor running status and diagnosis results are displayed through charts and text, so as to realize remote monitoring and fault diagnosis of the motor.

Methods

Common motor faults

Whether it is industrial production or household appliances, motors will frequently appear in our vision. When the motor runs continuously for a long time, its internal structure and parts will be damaged, and motor failure is easy to occur. In order to reduce the possibility of failure and avoid a series of serious effects caused by failure as much as possible, it is necessary to carry out more extensive research on this technology. The causes of each kind of fault are different, but some of them show similar fault symptoms, which is difficult to distinguish, so it is difficult to accurately locate and determine the nature of the fault in the diagnosis process. There are many kinds of motor faults, which can generally be summarized as mechanical faults and electrical faults, among which the most common faults are air gap eccentricity, stator, rotor faults and bearing faults. Motor faults are divided into mechanical faults and electrical faults, and some common motor faults are introduced in detail. In motor failure, the motor bearing is one of the most vulnerable parts of the motor. According to the relevant statistical data, motor faults caused by the damage of rolling bearings account for about 40% of the total motor faults, faults of stator coils and their accessories account for about 38%, faults of rotor windings and their accessories account for about 10%, and faults of other types account for about 12%. The rolling bearing of motor is the most common fault, so the research on bearing fault is also very important. Among them, the faults of inner and outer rings of rolling bearings to varying degrees belong to mechanical faults, while the faults of Hall sensors and rotor eccentricity belong to electrical faults. The eight different types of faults are studied, respectively, and the vibration signals of eight different fault motors are collected. Through the monitoring and analysis of the motor vibration signals, the effective information containing a large number of motor operating states is obtained to achieve the classification of motor faults [8].

Design of system architecture

The system adopts a 3-tier architecture of the IoT technology, with a perception layer (data collection), a transmission layer (data transmission), and an application layer (calculation and display data), as shown in fig. 1. Support vector machine is used to realize remote monitoring and fault diagnosis of motor. The sensing layer is composed of various sensors of the controller, which is responsible for collecting signals such as motor vibration, voltage, current and temperature. After obtaining the operating parameters of the motor, the controller packs the data into a specific format. The transmission layer is the central area of the system, which is composed of servers, wireless modules and databases. The main work of this part: data in the database according to the established format and listen to the connection request of the client and respond to the data request instruction of the client. The client and server use Socket for data transmission based on TCP/IP protocol [9]. After the connection between the server and the client is successful, the server will parse the request command sent by the client, take the corresponding data from the database, package the data into Json format, and send it back to the client. The interaction process is shown in fig. 2. The application layer is the mobile terminal software (Android system), which is responsible for showing the running state of the motor to the user. The software is developed on the Android Studio platform, and the programming languages are Java and Kotlin. The main functional modules are shown in fig. 3.

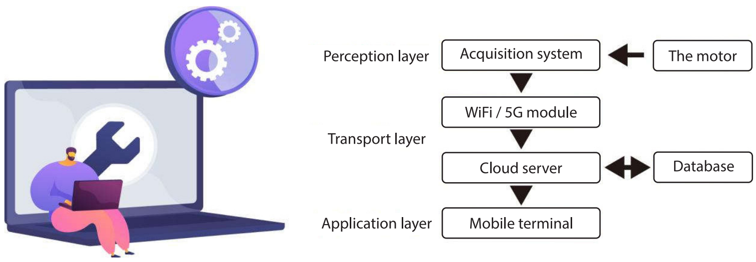

Figure 1. Structure of remote monitoring system

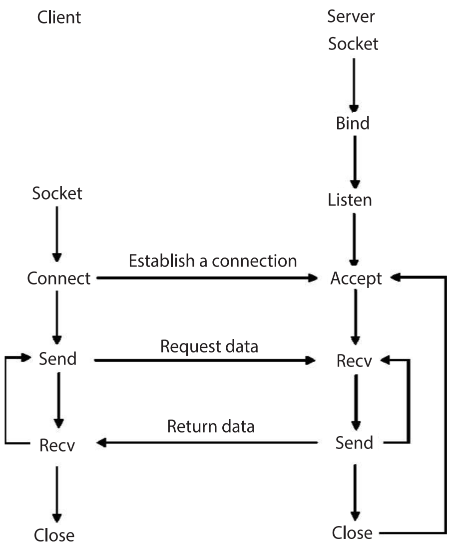

Figure 2. Customer server interaction process

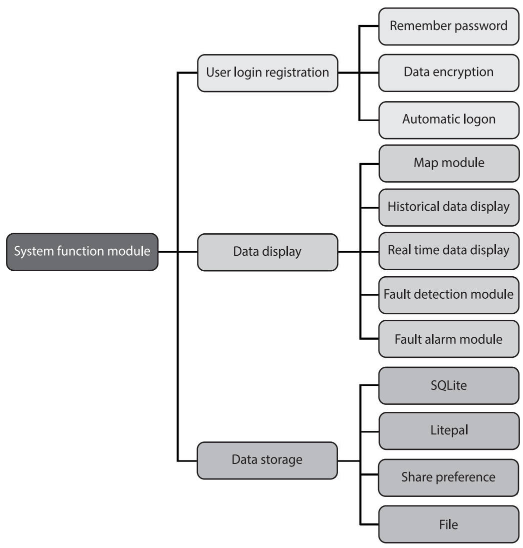

Figure 3. Functional module of mobile terminal software

Basic principle of fault diagnosis

In a complex system, some important equipment will have a very bad impact on the system if they are damaged and eventually lead to failure. Fault diagnosis technology is the key technology of complex industrial processes and mechanical equipment normal and stable operation, which has extremely important research significance. The purpose is: under the condition that the equipment is not shut down or disassembled, through some means and methods, the effective information of equipment operation is measured, and the useful information obtained is convenient for observing the abnormal conditions of the equipment, understanding the status of the equipment at all times, and even identifying the specific location information and causes of the failure, so that technicians can timely grasp the failure trend and remaining life of the equipment [10]. Signal processing, artificial intelligence, pattern recognition and other knowledge are closely related to the research of fault diagnosis technology, in recent years, this technology is in the stage of continuous innovation and improvement. With the continuous reform and innovation of this technology and more demands in the market, more fault diagnosis methods have also emerged. Currently, fault diagnosis methods mainly include three categories: the earlier mathematical model method, the more widely used signal processing diagnosis method and the more intelligent artificial intelligence diagnosis method.

The GA-SVM model fault diagnosis process

The process of fault diagnosis and GA algorithm optimization parameters of GA-SVM model is shown in fig. 4.

Calculate the eigenvector. The time domain parameters of vibration signals are selected as eigenvectors in the system. The characteristic vectors *[pk*, *va*, *rm*, *ku*, *S*, *C*, *I*, *L*, *K*] of the signal are composed of the peak to peak value, *pk*, variance, *va*, mean square value, *rm*, kurtosis, *ku*, waveform factor, *S*, peak factor, *C*, pulse factor, *I*, margin factor, *L*, and kurtosis factor, *K*, extracted from the vibration signal. The number of training set and test set samples is 300 and 100, respectively. The sample set is randomly allocated to avoid the impact of sample distribution on the results [11].

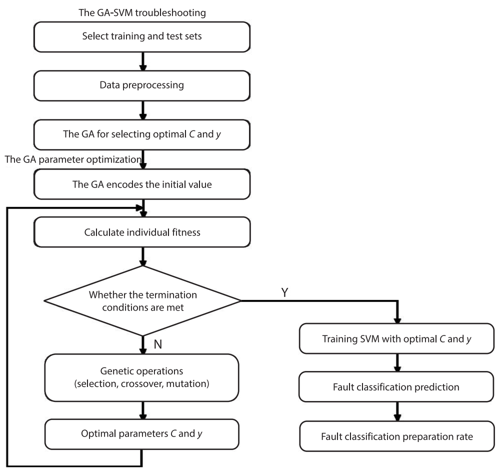

Figure 4. Fault diagnosis process based on GA-SVM

Data preprocessing. The training set and test set are preprocessed by interval normalization reduce the difference between values and keep the variation amplitude of each parameter in a certain range. After normalization, the data is adjusted to the [0, 1] range. Use GA to calculate the parameters C and γ optimization. Main steps: Set C and γ Binary coding, generation of initial population, calculation of fitness function, selection, crossover and mutation operations. In initialization, set the number of iterations to 50, the population size to 20, C and γ. The optimization area of is [0100], the cross probability is 0.4, the variation probability is 0.2, and the K in cross validation is 4. Establish GA-SVM fault diagnosis model. Using [C, γ]. Taking training set as input parameter, GA-SVM fault diagnosis model is obtained through training [12].

Use GA-SVM model for fault diagnosis. By comparing the difference between the fault detection test results and the ideal results, the possibility of motor fault can be obtained.

Results and discussion

In order to measure the fault diagnosis performance of GA-SVM model, GA-SVM, PNN, KNN, and clustering algorithm based on Kohonen network are, respectively used to train and predict the same sample set. The GA-SVM uses RBF kernel function, model parameters *C* and γ 30.8 and 4.3, respectively. The diagnosis results are shown in tab. 1 and fig. 5. For other neural network models, the accuracy curve of GA-SVM is relatively stable, because in the case of small samples, the neural network adopts the principle of empirical risk minimization. The GA-SVM model adopts the principle of structural risk minimization, which improves the generalization ability of the model. At the same time, the training sample characteristics of SVM model make the model have better robustness and generalization energy through RBF kernel function [13].

Table 1. Diagnostic results of different models (accuracy) [%]

Clustering algorithm			
GA-SVM	PNN	KNN	Kohonen
99	89	92	89
98	82	88	80
96	78	89	71
99	88	97	95
99	91	91	90
95	79	81	71
99	92	92	94
100	84	90	96
100	98	99	87
99	87	92	87

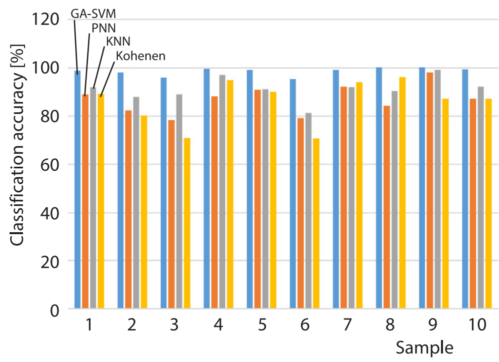

Figure 5. Curve chart of fault classification accuracy of different models

Table 2. Test results of GA-SVM on mobile terminal

Accuracy [%]	Running time [ms]
100	30
98	14
96	15
99	15
99	12
95	15
99	12
100	11
100	13
99	10

Use LIBSVM software package to program in Android Studio. The fault diagnosis test results of GA-SVM at the mobile terminal are listed in tab. 2. It can be seen from tab. 2 that when GA-SVM is running on the mobile terminal, the fault detection accuracy is high and the running time is short. Therefore, the model is suitable for mobile terminal fault diagnosis [14-18].

Conclusion

To sum up, the author designed a motor remote monitoring and fault diagnosis system for the mobile terminal, which can realize the condition monitoring and fault diagnosis of the motor *anytime, anywhere*. The system consists of data acquisition part, server and mobile terminal. In the system, the data acquisition part of the motor can obtain the running parameters of the motor in real time and transmit them to the server. The server stores data according to the established format and responds to the data request of the mobile terminal. The user can monitor the running state of the motor in real time through the mobile terminal. The mobile terminal uses the fault detection method based on GA-SVM model with high accuracy and short detection time.

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