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Laser Cutting Machine Tool Monitoring and Assistance System Based on Internet of Things and Cloud Service

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Abstract. With the development of computer technology and the increasing application of Internet of Things technology, traditional monitoring and assistance system for laser cutting machine tools can no longer meet the needs of Intelligent Manufacturing in modern enterprises. We proposed a remote monitoring and assistance system based on Internet of Things and cloud services for the laser cutting machine tools. STM32 chip is selected for field data acquisition and ESP32 chip is selected for the WIFI gateway. Cloud monitoring system is implemented IoT on platform and Elastic Computer Service. Monitoring and interaction software is developed in mobile phones and local PC. Laboratory tests show that the system is feasible for the improvement of production and maintenance efficiency of laser cutting machine and provide a low-cost remote diagnosis and maintenance system for laser processing enterprises and laser cutting machine tool manufacturers.

1. Introduction

With the development of the Internet of Things (IoT) technology, the requirements for technical and intelligent of enterprises' manufacturing equipment are increasing accordingly[1], therefore, the maintenance of large equipment in manufacturing enterprises is becoming more and more complex. In order to improve production efficiency, production enterprises are attaching more importance to the maintenance efficiency of large equipment [2]. The traditional equipment maintenance is generally carried out by the technical personnel of the equipment manufacturing enterprise in the user's site, however, which cannot meet the requirements of the production enterprise today. In this case, the remote diagnosis technology based on the IoT provides a solution. This technology is realized in the way that: a device status monitoring module is installed on the production equipment site, used to collecting status data of the large equipment in real time, and the collected data can be transmitted to the cloud server remotely through the enterprise Internet or 4G wireless communication module[1, 2]. By the establishment of the remote diagnostic expert system, the remote assistance and online technical support can be provided to the user. However, due to technical or financial limitation, the above-mentioned remote diagnosis and maintenance system cannot be established and maintained by the production enterprise or device manufacturer[3].

Like other equipment monitoring systems, the architecture of the remote diagnosis and maintenance system of the present machine tool mainly includes B/S mode, C/S mode and B/S+C/S hybrid mode. The remote fault diagnosis system based on B/S mode generally has three tiers: central server, database server and client. The users access the remote diagnosis center through the browser. The advantage of this mode is flexible and open and the disadvantage is that the enterprise needs to develop a remote diagnosis center, which requires professional technician to maintain, and the use cost is high. The remote fault diagnosis system based on C/S mode generally has two tiers, namely, the central server and a client.



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It is an early mode. The advantage is that the server has low requirements, but the subsequent maintenance cost and workload are large, and the flexibility is poor. Therefore, some scholars proposed a hybrid remote diagnosis system, which fully utilizes the advantages of B/S mode and C/S mode, and its design and development meets actual needs [7]. Although it overcomes the shortcomings of the remote diagnosis system based on the B/S mode, and will the diagnostic center is set in the technical support center of the device manufacturer, and is maintained by a professional technician, and show certain advantages over a period of time. However, in the hybrid mode, the user needs to be built a local monitoring center on site, and the local monitoring center needs to communicate with the device manufacturer. In addition, the production site also needs technical personnel for management and maintenance. Therefore, it is not suitable for the application in small enterprises[3].

With the rapid development of cloud computing technology, the cost of computing has dropped significantly[4, 5]. The big data technology provides a powerful basis for macro analysis and intelligent decision making. At the same time, the emergence of the public IoT platform also provides a better way for remote intelligent monitoring of equipment[6]. Therefore, it is possible to achieve centralized monitoring in the laser cutting machine tool industry, which relying on IoT technology, cloud computing technology, machine tool big data[7, 8]. Based on the above analysis, in view of the shortcomings of the existing remote monitoring and assistance system for the laser cutting machine tool industry, combined with the current mature IoT and cloud service technology, in this paper, we propose a laser cutting machine remote monitoring and fault diagnosis system based on the IoT and cloud services. Every machine tool is connected to the IoT platform, and the field user and machine tool manufacturer technician can access the cloud service center through the client, which not only can realize equipment monitoring and maintenance, but also realize remote fault diagnosis and assistance[9]. The proposed system scheme provides a feasible solution for intelligent manufacturing in the field of laser processing.

2. System Structure

The overall structure of the intelligent monitoring and diagnosis system for laser cutting machine tool based on the IoT and cloud services is shown in Figure 1. The system is mainly composed of three parts: gateway equipment, cloud service center and client (user and device manufacturer technical support engineer). The gateway device can not only realize the acquisition and remote control of key data of the field machine tool, but also realize the mutual communication with the IoT platform and the cloud service center. The data of each machine tool is transmitted to the IoT platform through the enterprise Internet or the 4G wireless communication network and receiving various instructions issued by the IoT platform. The cloud service center consists of the IoT platform and the cloud server. The IoT platform is a public IoT platform, can realize the acquisition and processing of the operational status information and control commands of the field devices.

The cloud server provides an intelligent diagnostic application for troubleshooting, which is responsible for storing, managing, analyzing and processing the status data, historical diagnostic data, and the other data of the equipment. The client is mainly used by enterprise managers and technician, and it includes including networked field monitoring computers and mobile devices. The local computer and the cloud server adopt the B/S structure, namely, the device monitoring is implemented through a PC browser. The mobile device mainly executes device monitoring through the smart phone APP. The cloud service center diagnostics staff client consists of technician from device manufacturer or research institutes, who can handle the remote diagnostic requests from the client at any place through the cloud service center. In this mode, the diagnostic center is managed and maintained by the cloud service provider, and the enterprise can connect the device to the diagnostic center only through a cloud gateway.

2.1. Work Flow of the System

The work flow of the system includes the following steps: authentication, automatic fault diagnosis, online troubleshooting, remote real-time debugging and maintenance reminder.

2.1.1. Authentication. After the field device is connected to the cloud gateway, it must pass the authentication before connected to the cloud service center. The field technician and the manufacture

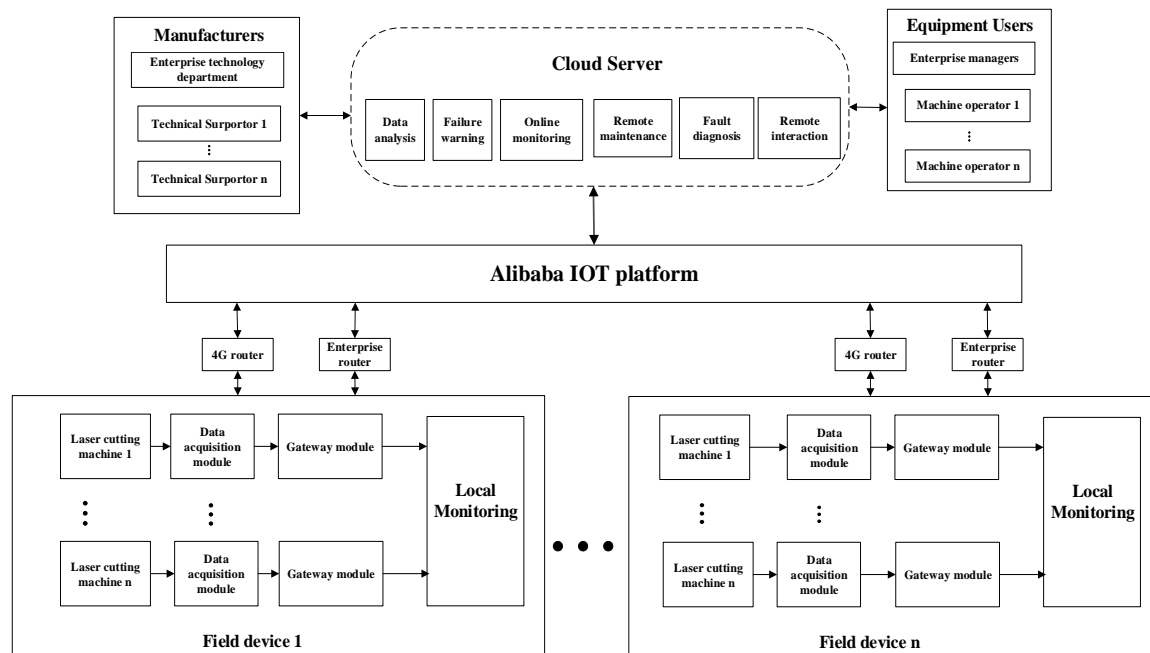


figure 1. Block Diagram of the Overall System

diagnosticians must pass the authentication before logging into the cloud service center. If the field device is connected to the cloud service center for the first time, the user also needs to upload the related parameter field information of the device to the cloud service center, so that the service center creates a database table according to such parameter field information to save the parameter information of the device, and allocates corresponding identifier for that type of device.

2.1.2. Automatic fault diagnosis. When the device is connected with the cloud gateway and successfully logs in to the cloud service center, the cloud gateway will automatically collect the device status information and uploads it to the cloud server. The cloud service center will search for the historical diagnosis information of that type of device according to the identifier of the device, and then send the search results to the user. The user will decide whether to end the remote diagnosis process or select online troubleshooting or remote real-time debugging according to the information fed back by the cloud service center.

2.1.3. Online troubleshooting. The user communicates with the technician online, detailing the fault status of the device to the technician, and then the technician will guide the user to eliminate the fault of the device according to the user's description.

2.1.4. Remote real-time debugging. The technician operates the device directly through the cloud gateway, and observes the operation status of the device through the net camera. The relevant parameters of laser cutting machine tools can be set and adjusted remotely.

2.1.5. Maintenance reminder. The life of the machine tool is greatly related to its own quality, but the reasonable and effective maintenance measures can also extend the life of the device, and can also avoid some faults. The device operation record is sent to the cloud server, and the server expert system can automatically make a judgment based on the operation record of the device, and remind the customer to perform maintenance in time, which reducing the loss of the customer, and decreasing the maintenance workload of the device manufacturer.

3. Key Technology

3.1. Hardware Design of Field Gateway

The field gateway module is responsible for collecting and uploading the device fault data, and for receiving the feedback information from the cloud service center. Generally, the working environment of laser processing enterprises is complex, and the system is required to have a reliability. With the sensor technology, various sensors are installed in the machine tool[10], such as temperature sensors, pressure sensors, vibration sensors, voltage sensors, displacement sensors, speed sensors, and laser sensors, used to detect the operation status of the machine tool's motion axes, cutting head, water system, and gas system as well as other mechanical or electrical components in machine body[13,14].

For the data acquisition module, therefore, the field gateway module is designed based on the STM32-series embedded chip and the IoT ESP32 chip; and its hardware structure is as shown in Figure 2. Considering that if all data is stored and processed only by the cloud server, once the network is interrupted, the data will be lost, so we use both local data storage and cloud server storage, then, the cloud gateway needs a special data storage module.

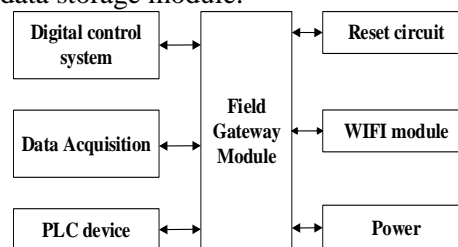


figure 2. Structure of the Field Cloud Gateway Module

The core chip of the field data acquisition module used the STMicroelectronics STM32F103-series microcontroller, with rich peripheral interfaces, low cost and low power consumption, fully meeting the needs of field data acquisition and communication. Given the diversity of field data acquisition signals, in addition to switch signal and analog signal, there is also data acquisitions that need to be realized through communication, such as serial communication, CAN communication, as well as communication to be realized through Ethernet, therefore, the field data acquisition module must meet needs of diverse ports [15].

The field data acquisition module achieves communication with the cloud server through the field LAN, and achieves wireless communication with an enterprise router or a 4G router through an ESP32 module. The communication protocol adopts the relatively-mature MQTT protocol, which can quickly connect the field device data to the Alibaba Cloud IoT platform.

3.2. Software Design

The software for the field data acquisition module is developed in C language. The field data acquisition software mainly includes six parts: the device driver module, system parameter initialization module, data acquisition module, device communication module, network communication module and LCD display module. The system initialization module is responsible for completing the setting of working parameters after the system is powered on; the device communication module adopts dual network card settings, can achieve redundant backup of the data transmission link. The network first selects the router of the enterprise Internet. When the enterprise Internet fails, the system will automatically switch to use the 4G router, which can ensure that data forwarding is not interrupted. The dual-network redundancy design enables the field device data can be transmitted to the IoT platform in time, so that the client can timely understand the operation of the laser machine tool, which can shorten the fault response time, and greatly improve the operation and maintenance efficiency.

After the device information acquisition and device parameter settings are completed, the system will become compatible with various communication protocols, such as Modbus, CAN, PPI. The network communication module can achieve the information interaction of the IoT platform in the form of WIFI IoT communication. The liquid crystal display module can realize the field display of data and

parameters, facilitating the human-machine interaction. The field IoT access chip is ESP32 chip, and it uses serial communication to communicate with the data acquisition module. The detailed control flow chart of ESP32 is as shown in Figure 3.

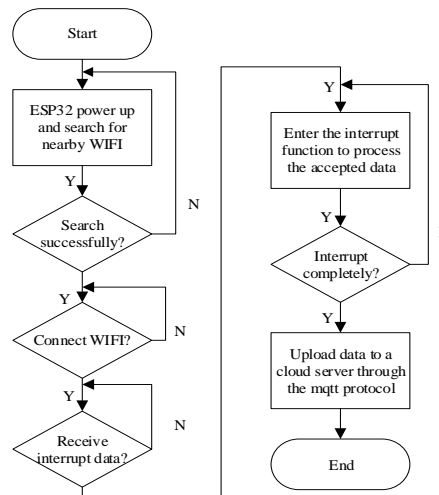


Figure 3. ESP32 Communication Process Flow Chart

3.3. Access of the IoT platform

In consideration of the security and stability of the system, the cloud service center manages the field device based on the Alibaba Cloud. Of course, it can also be based on any other IoT cloud platforms such as the OneNET device cloud. Alibaba Cloud IoT Platform is an open IoT cloud platform built by Alibaba Company. It can provide secure and reliable connection and communication capabilities for various devices and can be connected with a very large number of devices where the collected data is transmitted and stored to the cloud and the data can be downloaded to the local for analysis and storage. The IoT platform provide the cloud API to push the data to other cloud platforms actively, and the third-party application can send the commend data, which will be downloaded to the device and achieve the remote control. The structure of the Alibaba Cloud IoT Platform is as shown in Figure 4.

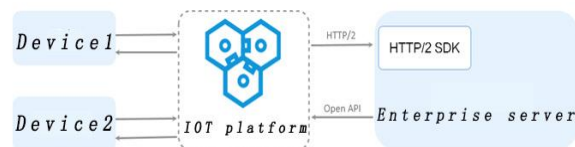


figure 4. Structure of the Alibaba Cloud IoT Platform

The Alibaba Cloud IoT platform access process is as shown in Figure 5. The user needs to register an account before accessing the Alibaba Cloud IoT platform, and then enter the IoT platform console under the user account, where, you can create the product and device, and then establish the connection between the device and the IoT platform. The Alibaba Cloud IoT platform provides the device-side SDK. The device uses the SDK to establish communication with the platform. After the device is connected to the IoT platform, the data is directly reported to the platform. The data on the platform can be transferred to your server through the HTTP channel. A third-party server can receive the device data by accessing the HTTP SDK. After the device successfully reports the message, commands can be sent to the device from the cloud.

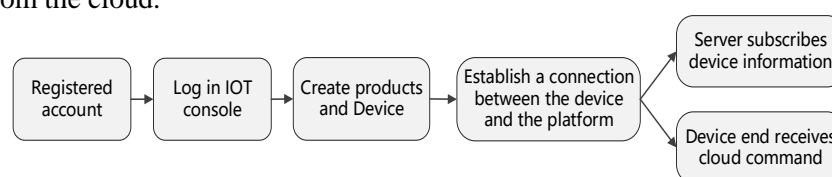


figure 5. Alibaba Cloud Device Access Process

4. Experimental Verification

According to the above design scheme, a prototype was developed in the laboratory environment for experimental verification. Firstly, the STM32-based field data acquisition module was designed and developed, which realized the field data acquisition. Then the communication gateway was realized through the use of the ESP32 module. The field device was connected to the Alibaba Cloud Server. The program of the Cloud Service Center analyzed and stored the data through the IoT Platform API, for viewing and processing by the user and technician. The field user monitored the operation status of the field device through the mobile phone client side or by logging into the webpage of the cloud service center through a browser.

The laser cutting machine tool and the gateway module were connected by a serial module, and the communication baud rate was 115200. The gateway module communicated with the cloud server through the industrial Ethernet, and the user, the technician and the cloud service center were connected through the network. The cloud service center was deployed onto the Alibaba Cloud, its operating system was Windows server, and database was SQLServer2008. The system application was mainly used to achieve functions such as authentication, device status monitoring, as well as analysis, storage and query of the device status parameter information. The monitoring picture of the local system and mobile phone is shown in Figure 6

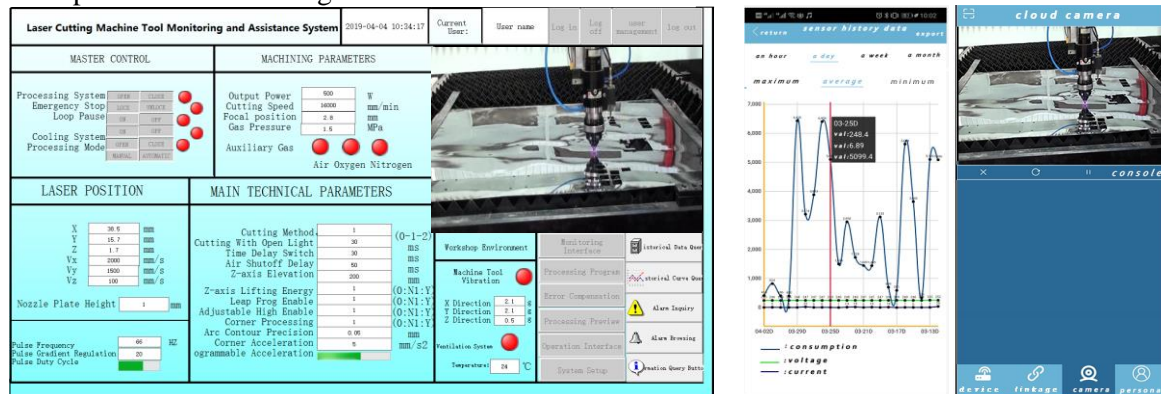


figure 6. Monitoring pictures in PC and mobile phone

5. Conclusion

Considering that the traditional remote device diagnostic technology cannot meet the needs of the development of current enterprises, we designed a remote diagnosis and assistance system based on the IoT and cloud services, on the basis of the public cloud platform of the IoT, which can not only realize the local status monitoring of the machine tool, but also can upload the running parameters of the laser cutting machine to the IoT platform in real time through the IoT module, to achieve monitoring, analysis and storage of data via the cloud server, thus an online diagnostic platform is set up so that the user and the technician can view and exchange technical information. Relevant enterprises can entrust their own remote diagnostics business in the service center without having to build and maintain a remote diagnostic system, which greatly reduces the investment cost of enterprises, and also meets the needs of middle and small-sized enterprises, improving the equipment use and maintenance efficiency.

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