Research and application of Netty based condition monitoring system for forage harvesting machine

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Abstract. In order to realize intelligent monitoring of main components of forage harvesting machine, an intelligent remote monitoring system based on CAN bus technology, Socket communication protocol based on Netty framework and cloud server was designed to solve the problem of low level of informatization of forage harvesting machine in China. System includes data acquisition system, data wireless transmission module and cloud data storage and analysis and processing system, realizing the data synchronization and sharing of working condition information of forage harvesting machine at local, cloud and mobile terminals. We developed the onboard terminal system based on Labview platform, and the web server based on SpringBoot framework. The parameters obtained by the sensor mainly include vehicle position information, engine speed and torque, shredding roller, grain crushing roller, cutting table, feeding, throwing, motor and other core components. Field experiments for 15 consecutive days show that: cloud server system with custom Socket communication protocol receives and stores terminal data in real time; The monitoring platform can realize the functions of data display and curve display of working condition information, data analysis and intelligent information reminder. By analyzing the data curve of the main components, the stability and reliability of the system are verified, which is of great significance to the informationization and intelligent development of the machinery and equipment of the forage harvesting machine.

1. Introduction
The research on intelligent agricultural machinery is an important link in the development of "precision farming" and the innovation of engineering technology [1]. Mankind has entered the "Internet +" and "Big Data" information era where everything is connected. The agricultural machinery informatization is the important measures to improve land productivity, resource utilization, and the labor productivity, and to improve the quality of agricultural machinery operation, economic benefits and competitiveness of agricultural machinery enterprises. Informationization and intellectualized construction of modern agriculture is an important strategic [2].

In recent years, the quality and quantity of combine harvesters in China have been greatly improved. However, the combine harvesters in China are at the middle and low end, with relatively backward in information technology level and high failure rate. Abroad study of forage harvesting
machine informationization, intellectualized earlier have processed relatively mature green machine management system, such as: collocation HarvestLabTM 3000 can use John Deere (John Deere) unique AutoLOC cut length intelligent management system, using NIR near infrared spectrum technology, according to the real-time automatic adjustment of cutting length and dry matter content to maximize the quality of feed. John Deere uses its unique additive spraying system and flexible additive methods according to different additive applications to automatically monitor dry matter content and uses additives accurately to improve silage quality and reduce cost [3-4]. John Deere's latest tractor combine can use GPS, artificial intelligence and other sensing technologies to make real-time judgments about how, when and where to start harvesting [5-7]. There is several main machine of high-end green machine: a g Ronnie BIGX700, kele 870 series and John Deere 8500 series. The series’ integration, automation and intelligent level is very high, with the grain crushing, rub silk technology and metal detector, and other functions, forage grass cut evenly, dry matter content, high machining quality of green fodder, less nutrient loss, adaptability and stability is good. However, the price of the product is relatively high, ranging from 2 million yuan to 4.5 million yuan [8]. Foreign countries have been upgraded from hardware to software. Although the high level of automation, its high price has been beyond the domestic small and medium-sized users can bear the scope. Domestic still need to develop to meet the needs of China's market information and intelligence level of high level of green feeding machine.

Most of the domestic improvements to the forage harvesting machine are still in the improvement of the hardware, mainly concentrated on the low-end products, such as: machine in miele, fauns qz - 3000 a, 9265 long out four qz - 280, animal husbandry ze four qz - 14 a, etc. These models has significant improvement in product performance, safety and comfort than their generation [8]. But for the forage harvesting machine of the informatization, intelligent software is still in research stage, much less in popularization and application. Wang xin [9] et al. designed a network platform for integrated management of agricultural information based on heterogeneous data integration technology. There are few researches on the working condition monitoring system of forage harvesting machine in China, most of which are centered on the on-board terminal computer [10]. The application of metal detection system, intelligent fault alarm system and intelligent information feedback system and other high and new technologies is still in its infancy [11].

Based on the TCP long connection transmission framework of Netty [12-13], this paper designed a remote monitoring system for the working conditions of corn harvester, which separated data collection, data transmission and data analysis. It is of great significance to improve the traditional system by using the popular Internet development technology to realize the further connection between forage harvesting machine and Internet of things.

2. System scheme

The condition monitoring system of forage harvesting machine is mainly composed of monitoring terminal, data transmission interface and network platform, which realizes the stability, high frequency transmission and storage of the collected information of main working parts of forage harvesting machine and endows the visual function of information monitoring of forage harvesting machine. As shown in figure 1, the overall framework of the system is divided into four parts: physical layer, data acquisition layer, data processing layer and application layer.
Figure 1 general framework of the system

3. Monitoring terminal
The sensor is connected to the on-board terminal computer through CAN bus technology. The sensor types installed on the system include torque sensor, speed sensor, temperature and humidity sensor, and beidou positioning module.

The main hardware to be monitored are engine, shredding roller, fan, grain crushing, feeding roller displacement, feeding roller speed up and down, cutting table, throwing and real-time position of the whole machine. The sensor on each part is connected to the on-board terminal through CAN bus to realize data collection.

3.1. Installation of some sensors
Because green machine equipment in the production of no sensor installation space reserved ahead of time, some sensors installed meet a lot of inconvenience. Monitoring chopped roller speed sensors installed as shown in figure 2, monitoring the speed of the fan and the grain crushing sensors as shown in figure 3, monitoring of the feeding roller displacement sensor and the upper and lower feed roller speed sensors as shown in figure 4, the car terminal computer installation position as shown in figure 5.

Figure 2 Mincing roller
Figure 3 Fan and grain crushing
3.2. **On-board terminal system**

The sensor data acquisition system of forage harvesting machine is mainly based on the on-board computer system designed by Labview, which is mainly responsible for collecting working condition information of forage harvesting machine, standardized data processing, data transmission and real-time information display. The structure of the machine is complex. The frequency of data acquisition and transmission is not the same. We need sensor acquisition voltage, current, frequency and other electrical signals for processing for the acquisition system, which is transformed into a unified digital format. The 29 signals are for sorting, analysis, verification, preservation, and then through the serial port to the data transmission system. The system has its own display, which can display the real-time information in the form of graphs and tables, so that the driver can check the working conditions of the machine.

4. **Data transmission interface software design**

Data transmission interface is green machine condition monitoring system for the core of the centralized data processing and heterogeneous network data interaction. Vehicle terminal system send data through the serial port connection of GPRS DTU (GPRS data transfer unit) to the cloud server, without independent hardware circuit design, using a peripheral interface, stable signal, compatible with a variety of interfaces, which make full use of the advantages of the different hardware resources. The software runs on the on-board terminal computer, DTU and cloud server. Its main functions are: data format standardization, data wireless transmission, custom communication protocol and database management.

4.1. **Standardization of data formats**

This system carries on the data format optimization to the database table design, enhances the data universal. forage harvesting machine structure is complex; sensors, data types caused by a lack of precision of the sensor itself, as well as the engine of electromagnetic waves and the vibration of the machine operation, such as green feeding machine in the region, plant outside interference, lead to
numerical inaccurate data and disordered code. So it is necessary to standardize the data processing, using normalization, average, maximum and orthodontic treatment methods, such as characters. For example, if the longitude and latitude value of the positioning module is found to be garble code, the normal data of the nearest neighbor point shall be used as the value of this time. Within the same period T, the torque of the cutting table is the maximum value, and the speed of the cutting table is the average value.

4.2. Data wireless transmission

This system adopts 4G communication technology and CAN protocol to gather data from various sensors at the bottom and send them to the cloud server through DTU.

USR-G780 4G LTE DTU (figure 6) is adopted as the transmission tool, and the antenna and 4G card are added to open the USR-G780 v2.0.1 configuration software. Configuration parameters: baud rate: 38400, address and port number of the connection server, connection type: TCP long connection, and the heartbeat packet is set. After the configuration of various parameters is completed and the test is passed, it can be directly connected to the on-board terminal for use next time. For connections where there is no data interaction for a long time, connection resources are wasted. However, some scenarios are not excluded. Although the client and server do not exchange data for a long time, they still need to maintain the connection. This time, the heartbeat can be used to achieve.

Data sample:

20359740396|A|181019|230548|4551.987047|12302.34617|3.123|1.14|15.1|753.42|465.22|6.89|136.96|136.96|195.43|136.96|256.34|110.6|5.8|2.7|246.3|246.3|246.3|246.3|2|2|28.9|53.2|13.2|##

Figure 6 DTU

4.3. Custom communication protocol

The information of this system is mainly data obtained from various sensors installed on the forage harvesting machine, field crop information, and agricultural meteorological information. Once the sensor is successfully connected to the server, it needs to automatically upload data for a long time. Netty is a server framework that supports TCP long connection transmission. There are many types of sensors, the data types are different, and the frequency of data upload is high. This requires the real-time and accuracy of data transmission. Therefore, this system uses the Netty framework as the application framework and tool for the information transmission of the forage harvesting machine. Realize full-duplex data communication between vehicle terminals and cloud servers.

Netty is a Java open source framework for network programming based on NIO (non-blocked IO), which simplifies and streamline the development process of NIO. Netty is an asynchronous event-driven network application framework tool that facilitates the rapid development of high-performance and highly reliable network IO programs. It supports massive concurrency, and through its prefabricated coders and decoders, it can realize the parsing of different communication protocols and push the data to the message middleware in a unified json format. In this way, for application platforms such as supervision, operation and maintenance, the data format is unified, standardized and easy to use [14-15].
As the most popular NIO framework, Netty has been widely applied in Internet, big data distributed computing, game industry, communication industry, etc. The well-known Elastic search and Dubbo frameworks all adopt Netty.

4.4. Database framework design

The cloud system built by this system is the data storage server and data analysis system based on the embedded Linux operating system (CentOS7). Linux operating system server support hardware, security and stability, good portability, very suitable for green machine. This system database USES MySQL and NoSQL respectively.

The database is very important for forage harvesting machine and users, including not only the data table of forage harvesting machine working conditions, but also the basic information table of page users. In this design, the database mainly includes data collection table, user table, job quality analysis table, control table 4. The data table is mainly used to record the values collected by the sensor, as shown in table 1, including equipment number, successful positioning, longitude, latitude, lateral speed of the cutting table, lateral torque of the cutting table, vehicle speed, engine speed, etc. The user table mainly records the user's basic information, including account number, password, email, etc.

For the database of high frequency and high concurrent information under the working condition of forage harvesting machine, MySQL database is used and MyBatis framework is adopted to map the database to realize the communication between the on-board terminal and the cloud server. With the promotion of cluster operation, there will be a large number of user visits in the future, and the processing of business logic will also form high concurrency. Redis database is used, and Redis adopts NoSQL technology, a memory-based database, which can effectively improve the processing speed of business logic data.

| Table 1 Data collection table |
|-------------------------------|
| Meaning | Row header | Device number | Positioning state | latitude | longitude | header1_speed | ... | Amount of fuel |
| Name | id | eid | location_status | g_latitude | g_longitude | fuel_consumption |
| Type | int | int | varchar | varchar | varchar | varchar |
| Example | 175131 | 10359740396 | A/V | 3520.27499 | 11837.59138 | 1.147 |
| Unit | 14.1 | L/h |

5. Server network platform

The server network platform is used to display the working condition information and user operation of the forage harvesting machine, which is the channel connecting the user and the forage harvesting machine. The server is built based on the Spring Boot framework, with a three-tier architecture of presentation layer, business logic layer and data access layer. The processing and analysis of data are all put on the cloud server to relieve the pressure on the sensor data acquisition system of the forage harvesting machine and improve the ability of data operation. After the data processing, the processed results are pushed to the client in real time to realize data sharing and task collaboration between the on-board terminal and the cloud.

Through the computer, the system can directly see the working condition information of the machine. Through the database management tool (Navicat Premium), administrators and users can easily and quickly view the data in multiple database tables in the cloud server. Professional developers can more easily manage the data, facilitate the processing and analysis of the data. It is convenient for developers to use machine learning, AI and other ways to analyze and process data. Strong portability.

The cloud server is configured as CPU: 1 core, memory: 2 GiB, operating system: CentOS 7.3 64-bit, bandwidth: 1Mbps, hard disk capacity: 40G, maximum public network incoming bandwidth: 500Mb/s, maximum public network outgoing bandwidth: 1Mb/s. The length of a TCP communication string sent by a cyg locomotive carrier terminal is 182.
The display of information is divided into real-time information and historical information. The real-time display can let users know the current working state of the machine, and the historical display can provide the historical record of the machine for the analysts, providing data support for fault prediction, detection and efficiency improvement.

Information and intelligent functions of the system:

1) The beidou positioning module displays the real-time position of the vehicle and records the working hours and trajectory.

2) Intelligent voice reminder. When one or several data items in the sensor parameters are abnormal, it will give a quick alarm to remind the driver to stop for maintenance, reduce the loss and improve the safety of operation.

3) Real-time data display, enabling users to see accurate real-time data, convenient to monitor the working state of the machine.

6. practical application
From September to October 2019, the 4qz-350 self-walking green fodder harvester produced by wuzheng group was used for field test in Qingdao, and the operation lasted for 15 consecutive days to verify whether the accuracy and stability of the intelligent detection system met the requirements.

Frequency of data transmission: 400ms; length of string: 182; rotation speed of cutting table is set to high, medium and low respectively. When the cutting table is in the middle gear, the data analysis of the rotation speed and torque outside the cutting table in the operation of the forage harvesting machine is shown in figure 7. It can be seen from the figure that: under the normal operation of the forage harvesting machine in the field, the data id from 175180 to 175544 was used to analyze the data parameters of the main components, indicating that the sensor on the forage harvesting machine worked normally and achieved the expected goal of the system.

![Figure 7 Partial parameter curve](image)

7. Conclusion and prospect

1) Developed a unified data format for the working condition information collection terminal of the forage harvesting machine, and develop the communication channel between the on-board terminal computer and the cloud service -- the data transmission interface. The problem that the local data and cloud data of the monitoring system cannot be shared in real time is solved; the stability and reliability of system data reception and storage are ensured through a custom communication protocol.

2) Field experiments showed that the system runs stably, and the current netty framework popular on the Internet can be transplanted into agricultural machinery monitoring systems.

3) Through the installation of sensors and software control system on the main components, the automatic collection, complete storage and real-time monitoring of the working state information of the whole machine can be realized, and provide data support for the life evaluation, transformation and upgrading of the whole machine parts in the later period. The obtained work data provides a data basis for further improving the overall informatization and intelligence of the forage harvesting machine.

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