Multi-terminal Experimental System Based on Wireless Local Area Network

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Abstract. Aiming at the problems of single experimental data display, difficult data recording, poor human-computer interaction and low security for an experimental system, a multi-terminal experimental system based on Android operating system and wireless local area network was designed. Based on the Android operating system and wireless LAN, the system combines MySQL database, Web server, and LabVIEW software, and adopts modular design, realizes real-time collection and recording of experimental data during the experiment, and multi-parameters cross hardware display, good human-computer interface and remote status monitoring.

1. Introduction
The experimental teaching link in the course of aircraft engine principle is an important practical way to learn and understand the working principle of aero-engine. Due to the high cost of large-scale engine test bench, high maintenance and use cost, complicated process, etc., various colleges and universities use micro-turbojet engines to build experimental platforms to complete the corresponding experimental teaching needs.

A lot of substantive work has been done at home and abroad in setting up an experimental system for micro turbojet engines. The Karlsruhe Institute of Technology in Germany has established a complete test system for the independent development of micro-engines of the order of 100N. Nanjing University of Aeronautics and Astronautics designed a matching experimental system to study the wind turbine starting characteristics of the micro turbojet engine[1]. Beihang University designed a mobile engine experimental platform for the independent development of micro turbojet engines[2]. The above mature experimental platforms have been fully applied in the research process, but they are not suitable for the purpose of interaction with the engine test demonstration and teaching. They have the characteristics of poor expansion, versatility and low security. At the same time, due to the use of high-precision measuring equipment, there are disadvantages such as high cost and poor maintenance. Also, the existing micro turbojet engine test bench in the course teaching has the problems of single experimental parameter display, difficult data recording, poor human-computer interaction and low safety.

In order to solve the above problems, a multi-terminal experimental system based on wireless local area network was designed and developed to realize cross-platform, long-distance, multi-terminal display of experimental data. The system redesigns the original micro turbojet engine test bench. Based on Android system and wireless LAN[3][4], it uses Labview software, MySQL database, Web server, human-computer interaction interface, serial port and network communication technology to
realize cross-platform and long-distance bidirectional transmission of experimental data and instructions, ensuring the safety of experiments and increasing the participation of experiments.

2. Overall system design
The multi-terminal extension module is composed of an Android mobile terminal and a web server, and mainly completes experimental data transmission, display, recording, and transmission of Android terminal instructions. The computer data terminal establishes communication with the web server through the MySQL database. The overall block diagram of the multi-terminal experimental platform system based on the local area network is shown in Figure 1.

3. Wireless data transmission module
The wireless data transmission function is composed of a web server and a wireless router built on a computer. Compared with the WLAN LAN built with WiFi module, NFC and Bluetooth, the use of Web server and wireless router to build a LAN has the advantages of large coverage, large number of access, long transmission distance and fast transmission speed.

4. System software design
The system software design is mainly divided into four parts: LabVIEW PC software design, embedded measurement and control board program design, Web application design and Android mobile terminal experimental application software design.

4.1. LabVIEW PC software design
The PC software needs to implement four functions:
- Communicate with embedded measurement and control board.
- Real-time display of experimental data.
- Experimental data recording and playback.
- Communication with data and instruction information with Mysql database.

The software is developed using LabVIEW image programming software under Windows system to ensure high versatility of the PC software and reduce development time\(^\text{[5]}\).

Real-time communication with the measurement board and communication with the MySQL database is the core of the host computer program. The program uses the VISA (Virtual Instruments Software Architecture) control in LabVIEW software to call the serial port of the computer to realize RS232 serial communication\(^\text{[6]}\). Communicate Labview program with MySQL database by using LabSQL database access tool running on Labview and MySQL odbc connector plugin. VISA is a standard I/O application interface for instrument programming. It can call the corresponding driver according to the type of instrument used, including GPIB, serial port, USB and other drivers, which can effectively reduce development time and difficulty.
4.2. Design of experimental application software based on Android
The client in the design is developed and upward compatible based on the Android 4.0.3 version. The client uses the network communication to accept the experimental data. The built-in lightweight relational database SQLite is used to store the experimental data, and the data is displayed intuitively and dynamically by using the ProgressBar, the TextView and the achartengine icon frame.

Web server is built by using Tomcat as a container of Servlet to publish and run a web application, and is used to parse the network request of the Android client in the wireless local area network, and according to the client's corresponding request to perform operations such as querying, inserting, updating, and deleting records of the MySQL database, and returning corresponding response results to the client. In the design, the web application accesses the MySQL database through the JDBC driver, and improves the access efficiency of the database by configuring the data source.

4.3. MySQL database
As an important node for data and instruction exchange, the database is essential for data and instruction exchange of the overall system. The MySQL database used in the design is a free open source, small relational database with small size, simple configuration, good stability and excellent performance. It is very suitable for the development of small and medium-sized applications. Because of the SQL language, it is convenient for Web applications and LabVIEW software to record, update, query and delete experimental data.

4.4. Network communication
The system uses Hypertext Transfer Protocol (HTTP) to access the WLAN to communicate with the Web server. HTTP transmits data based on TCP/IP communication protocol, adopts client/server communication mode, and encapsulates client-server communication details internally. In the client software design, the HttpURLConnection class in the jar.net package that comes with the SDK is used to obtain the instantiated object through the openConnection() method to send the HTTP request and obtain the HTTP response\(^7\), using the default GET method\(^8\). Real-time monitoring of the experimental system by transmitting the operation instructions of the client by means of "link address + ? parameter name = parameter value". When a normal user accesses the wireless network of the experimental system, the system adopts DHCP\(^9\) technology to automatically assign different IP addresses according to the MAC address of the accessed mobile terminal. The IP address is assigned a unique serial number (incremented by 1) and displayed on the client software. The administrator can implement the temporary control of the experimental system by the ordinary user of the serial number by means of authorization for the specific serial number.

4.5. Authorization method
The Android client permissions are divided into administrators and ordinary users, which are distinguished by the client login password. When the password is entered correctly, the client software will treat it as an administrator and give it administrator privileges. When a normal user accesses the wireless network of the experimental system, the system adopts DHCP technology to automatically assign different IP addresses according to the MAC address of the accessed mobile terminal. The IP address is assigned a unique serial number (incremented by 1) and displayed on the client software. The administrator can implement the temporary control of the experimental system by the ordinary user of the serial number by means of authorization for the specific serial number. The specific authorization process is shown in Figure 2.
Authorized way to give an ordinary user control authority to the experimental system, while unauthorized users cannot obtain control of the experimental system, avoiding interference from other users of the access system to the experimental system, improving system security and stability, and increasing the participation of ordinary users in the experiment.

5. Data processing
In order to ensure the authenticity and stability of the experimental data during the experiment and prevent the influence of bad values, the median filtering method is used to process the original data \([10]\).

Median filtering is a commonly used nonlinear smoothing filter. It is a domain operation, similar to convolution, but not a weighted summation calculation. Instead, it sorts the data in the field by value and then selects the middle value of the group as the output value. It has a good filtering effect on impulse noise. The median filtering algorithm is as follows:

\[
out = med\left( data_1, data_2, \ldots, data_n \right)
\]

In the design, the STM embedded measurement and control board measures at a frequency of 550 Hz, and the median filter window length is set to 11, the bubble value algorithm is used to sort the original values, and the intermediate value of the set of data is considered to be a valid value. The timer output data frequency is 30 Hz.

6. Experimental evaluation
In order to realize the long-distance, multi-terminal display of the micro turbojet engine experimental data, the system is based on the Android operating system, combined with MySQL database, Web server and Labview software. Use serial communication technology and HTTP technology based on TCP/IP communication protocol, and finally set the authorization function. The purpose is to extend the advantages of multi-terminal participation experiments under the premise of ensuring experimental stability, so that users of the access system can participate in the control of the experiment.

The authorization function is through a relatively complex logical relationship. With the cooperation of the components in the Android SDK with the database and the web server, only one non-administrator terminal can have control over the experimental system at the same time. And the administrator has the ability to monitor the entire experimental process.

According to the design requirements of the system and the test requirements of the micro turbojet engine system, the main parameters of the experimental system are set as shown in Table 1, and the interconnection test is performed.
Tab.1 Experimental system performance setting

| Data rate (Kb/s) | Terminal access | Transmission frequency (Hz) |
|-----------------|-----------------|----------------------------|
| 112.5           | 14              | 30                         |

According to the parameters of Table 1, the experimental system works well. The administrator and the normal user can display the implementation data normally, and the experimental data can be saved in the file management of the mobile phone as a text file. The administrator terminal can display the number of accessing ordinary users and the corresponding serial number.

Fig. 3 Client test curve

By authorizing, the ordinary user can obtain the corresponding control authority, and the user can normally manipulate the experimental system. The test curve of the Android client part is shown in Fig. 3. Three typical experimental data are extracted from the text file as shown in Table 2, which are the stop state, the idle state and the 90% throttle state.

Tab.2 Typical experimental data

|                | Thrust(dN) | Rotating speed(r pm) | Exhaust gas temperature(℃) | Atmospheric pressure(KPa) |
|----------------|------------|----------------------|----------------------------|---------------------------|
| Stop State     | 0          | 0                    | 23                         | 98                        |
| Idle State     | 4          | 35910                | 439                        | 98                        |
| 90% throttle state | 50        | 91746                | 398                        | 98                        |

Figure 3 is analyzed. It can be seen from the temperature curve that the test system can better record the operating parameters of the micro turbojet engine when the engine is running stably. However, when the micro turbojet engine changes its working state, the followability of the parameter curve is poor. It shows that when the micro turbojet engine is stable after changing the throttle value, the data curve shows a transient change.

The possible reasons for the poor dynamic followability of the experimental system are as follows: 1) The format of the data packet used in data transmission is more complicated, which increases the processing time of Labview software and reduces the dynamic followability of the experimental system. 2) There are many Android clients connected, and the computer processing performance adopted by the experimental system is poor, which is insufficient to meet the requirements of dynamic followability on computer performance. 3) The median filtering algorithm eliminates the edge value data more seriously, and reduces the dynamic change of the data, especially when the computer processing speed is not high. In the improvement process, the median filter window value is set to 7, and the median filter + complementary filter is used to improve the dynamic followability of data. 

The complementary filtering algorithm is as follows:

\[ out_{new} = (k_1*out_{old} + k_2*data) \]

\[ out_{old} = out_{new} \]

\[ k_1 + k_2 = 1 \]

\( k_1 \) and \( k_2 \) are complementary filtering algorithm parameters, Take \( k_1 = 0.95, k_2 = 0.05 \).

Using a high-performance computer, change the packet format to: header + measurement control ID + data (fixed length).
After the improvement, the dynamic followability of the experimental system of this design has been greatly improved. The improved Android client part test curve is shown in Figure 4.

![Fig4. Improved client test curve](image)

7. In conclusion

The system is combined with the micro turbojet engine system. Based on the Android mobile terminal, a multi-terminal experimental system based on wireless LAN is developed by using MySQL database, Web server, embedded measurement and control version and LabVIEW software, combined with network communication and serial communication technology. The system realizes multi-terminal and long-distance display of experimental data, so that the display and storage of experimental data are freed from the constraints of the place, and the authorization function is set at the same time, the authority of the administrator and the ordinary user is distinguished, and the flexibility of the experiment is improved. The system can access the Internet through intranet penetration technology, so that experiments are not limited by distance. At the same time, the multi-terminal and permission-restricted mode can provide a certain reference for the experimental teaching and the construction of experimental systems with certain requirements for real-time performance.

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