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Design and Verification of a Workshop Environment Monitoring System Based on Multiple Communication Modes

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ABSTRACT. *A workshop environment monitoring system based on multiple communication modes which satisfies the requirements of workshop environment monitoring in manufacturing enterprises is designed in this paper. The environment monitoring system is mainly composed of an execution layer, a communication layer and a control layer. The whole system monitors the running states of the equipment and the running environment of the workshop through real-time data acquisition and analysis, ensuring the normal operation of the production line. At present, this proposed system has been applied in the workshop of photo production enterprises. The practical application shows that this system improves the efficiency of the workshop, and the production environment is monitored in real time, the production safety is protected simultaneously.*

KEYWORDS: *Multiple communication modes, Environment monitoring system, Workshop*

1. Introduction

At present, most domestic workshop environment monitoring systems use wired transmission mode which has the advantages of stable transmission and strong anti-interference ability. However, it also has the flaws such as difficult maintenance, trouble second refitting and high cost. Workshop environment monitoring systems using wireless transmission can solve these problems, but it is very easy to lose some characteristics of the signals and it may hard to guarantee the stability of information transmission when there are strong interference. There are no such problems if the environmental monitoring system based on multiple communication modes are employed, and thus multiple transmission protocols can be supported at the same time. Combining WIA, ZigBee, WIFI and RS485 wired communication technology, this paper has designed a workshop environment monitoring system which can be compatible with a variety of communication protocols. This system supports both wired and wireless communication, users only need to choose the

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equipment communication mode according to the field environment, achieving the establishments of a workshop network, the upload of environmental data and the monitoring of equipment system.

2. System DESIGN

According to the requirements of the workshop project, the production line needs to monitor not only the operation states of the machine tools, laser marking machines, four-axis robots, six-axis robots, three-dimensional warehouses and other workshop equipment, but also the environmental parameters of the workshop, such as temperature, humidity, PM2.5 concentration, smoke concentration, and so on. Moreover, the monitoring system should also record the these data in real time, and save the recorded results in a database for future record and inspection.

n order to satisfy this requirements mentioned above, a workshop environment monitoring system based on a variety of communication methods is presented in this paper. The proposed system is mainly composed of execution layer, communication layer and control layer, which is shown in Fig.1.

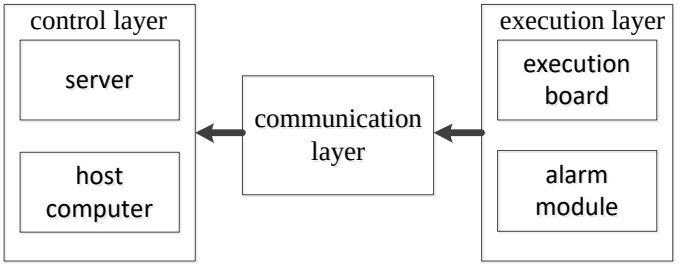

Figure. 1 The system composition block diagram

The execution layer in the diagram is mainly composed of data acquisition module and alarm module. The data acquisition module is responsible for collecting the environmental information of the workshop and uploading the collected data to the communication module; and the alarm module is responsible for receiving the control instructions issued by the application control layer and giving relevant alarms according to the control instructions.

The communication layer includes four kinds of communication modes, which are WIA, ZigBee, WIFI and RS485. The workshop acquisition equipment constructs the communication mode of each equipment acquisition module according to the field situation. The information transmission layer is responsible for uploading of environmental data and sending control instructions according to the communication mode of the equipment.

The control layer is composed of a server and a host computer. The server is used to store the environment parameters and the states of the equipment which are

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uploaded by the communication layer. The host computer will read and analyze the data stored in the database, and send the analyzed results to the perception and execution layer to control the running state of the equipment, ensuring the production safety of the workshop.

The proposed system adopts modular design, the environmental information and equipment states are monitored and controlled through the implementation board and communication board, Fig.2 has shown the composition of the execution board and multi-port board of this proposed system, and the execution board takes the CPU as the core to build the whole system. Among them, smoke sensors, temperature sensors, noise sensors, humidity sensors and fine particulate matter sensors are responsible for obtaining the actual data of the workshop, and the alarm module is used to respond to alarming instructions and display the information on the LCD screen. The data transmitting unit is responsible for transmitting the acquired data information to the communication board through the corresponding communication mode.

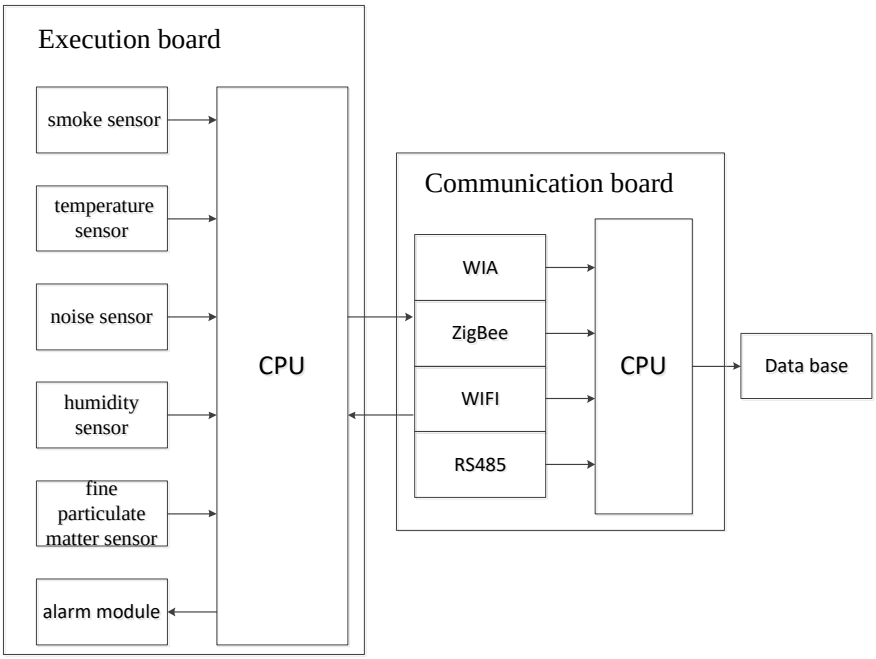

Figure. 2 system execution board and multi-port board

The communication board can construct a network layer and an application layer according to the physical layer and the media layer defined by the IEEE 802.15.4 standard. The constructed network services are distributed according to the communication protocol and reserved ports of the workshop equipment, thus a good matching of the equipment and the execution board can be achieved, and a reliable

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association between the communication board and the equipment can be established. The communication board is able to arrange the communication order of the execution board according to the distribution of the equipment and the network service of the equipment. The host core control module is responsible for protocol conversion and data analysis on the data uploaded by the execution board, and storing the analysis results in a database for further review.

3. Design of software

3.1 Data flow of environmental monitoring

The communication of wireless serial port is the key of the whole environment monitoring equipment. Its main function is to build service network. Fig.3 is the flow chart of the data communication.

According to Fig.3, we can divide the communication process into three main links as follows:

(1) First of all, the entire system initialization operation, a Communication Network Function is created;

(2) Next, a program polling cycle with a time limit of 10 seconds is created. The communication network acquires the information on the execution board through the query command in every 10 seconds.

(3) The communication network acquires the feedback of the query instruction. If the data feedback can be received, it will judge whether the data information of all execution boards is acquired or not, and the system executes ends if the data information is acquired. If not, the query instruction will be sent again, and the process will enter to no response step and count while the data is not received, and it will cycle to judge whether the data is received or not after sending query instructions more than three times.

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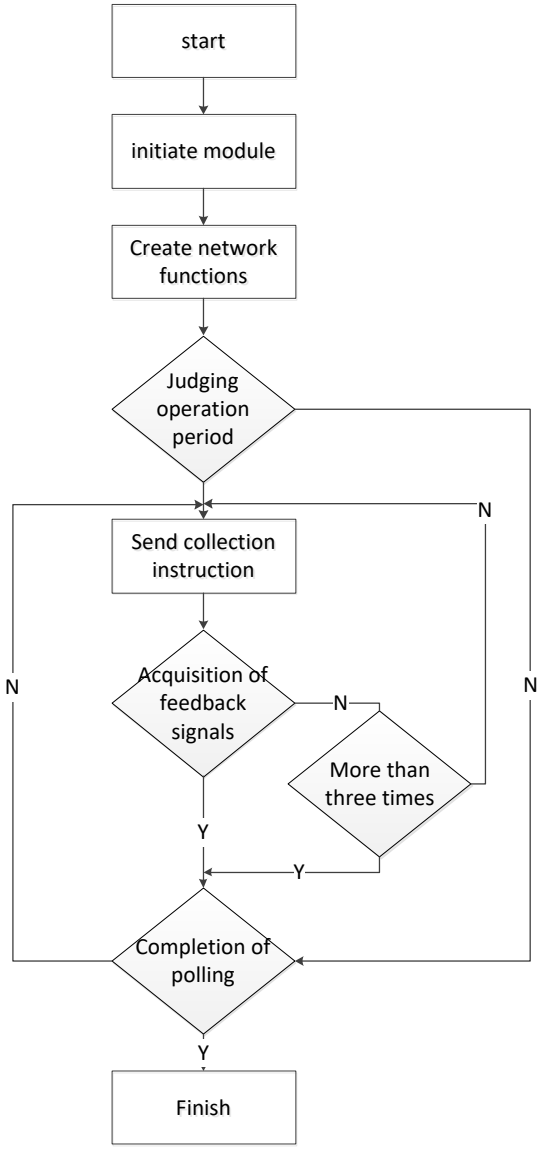

Figure. 3 The flow chart of data communication

3.2 Data processing method

The whole workshop can be regarded as matrix A, and the whole workshop is divided into several regions, which can be expressed as A1, A2 … AN, thus A={A1,A2…AN}, where N is the total number of the divided workshop areas.

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Let Ai={P1, P2 …PM}, PM∈Ai, where i=1, 2 … N, and M is the total number of devices which needs to be monitored in this workshop area.

Let Pj={Q1, Q2 … QT}, Qt∈Pj, where j=1, 2 …M, and T is the parameter that needs to be monitored on the equipment.

Let Qk={X1, X2 … Xe}, Xe∈Qk, where k=1, 2…T, and E is the collected equipment information.

According to the relationships expressed above, the perception model of the production line can be established, and the mean and variance of the same information parameters uploaded by all equipment in the workshop are taken as follows:

$$E(Q_K) = \frac{\sum_{i=1}^{n} X_i}{n} \tag{1}$$

$$Var(Q_k) = \frac{\sum_{i=1}^{n} X_i^2}{n} - E(Q_k)^2 \tag{2}$$

Assume Y is the safety state of the workshop equipment, and Y={0, 1}, where 0 means failure, and 1 means safety. Besides, Y can be expressed as

$$Y = Y_1 Y_2 \ldots Y_M \tag{3}$$

Where Y1, Y2 … YM satisfy the relations of the Boolean AND. YjY is the security state of the sensing region j, where Yj={0, 1}, which can be calculated as follows:

$$Y_j = S_1 S_2 \ldots S_T \tag{4}$$

Where S1, S2 … SM satisfy the relations of the Boolean AND, and St∈Y, where St={0, 1}, the security state of the state parameter Qt of the device. Assume that B={B1,B2,B3,…,BM} and C={C1,C2,C3,…,CM} are the upper limit of the data value and the safe value of the variance of the environmental monitoring parameters, respectively. When the mean and variance of the environmental monitoring satisfy the relations of $E(Qt) \geq Bt$ or $Var(Qt) \geq Ct$, St = 0, indicates that the presence of a danger alert in the perceived area. If Yj=0, Y = 0, indicates there are potential safety hazards in workshop equipment, the information will be uploaded to the control system to trigger alarm information at the same time; On the contrary, St=1 indicates that the workshop environment is within the safe value range.

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3.3 Experimental results and analysis

According to the designs of software and hardware mentioned above. The environmental monitoring data are compared with the real data of the workshop, and those environmental parameters are measured, which are shown in Table 1. It can be seen that the relative error of the system in temperature measurement is within ± 1%, the relative error in noise measurement is maintained within ± 1%, and the error in humidity measurement is maintained within ± 1%, the error in smoke measurement is maintained within ± 1%, the error in fine particulate matter measurement is maintained within ± 5%, so that the correctness of the data monitoring can be guaranteed for the whole system.

Table 1 Comparison of experimental data with actual data

Iitem	First	Second	Third	Fourth
Measured Temperature /℃	37.06	36.97	37.06	37.06
Measured Noise/dB	8.07	8.36	8.33	8.33
Measured Humidity /%	10.88	10.88	10.82	10.82
MeasuredSmoke /ppm	1284	1288	1281	1281
Measured Fine particulate matter μg/m^3	47	44	44	44
Ambient temperature /℃	37.12	37.02	37.11	37.11
Ambient Noise/dB	8.08	8.37	8.33	8.34
Ambient Humidity /%	10.79	10.82	10.75	10.76
Ambient Smoke /ppm	1283	1291	1280	1281
Ambient Fine Particulate Matter μg/m^3	46	44	44	44

4. Conclusion

This proposed system is designed to support WIA, RS485, WIFI and ZigBee these four kinds of technologies, which is based on a variety of communication modes of the workshop environmental monitoring system, this system can monitor the workshop equipment states and environmental parameters in real-time, and collect the workshop data accurately, which ensures the temperature, humidity, noise, smoke concentration acquisition error within ±1%, and the error of PM2.5 concentration collection is within ±5%. After a long period of testing, it is found that the whole system has good stability, which means it can't be affected easily by external factors. The system plays the role of monitoring the workshop environment, ensuring the safety of productions.

Acknowledgments

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