Study on the Internet of things system for dust migration control on excavation surface

Xiaoyan Gong¹, JianCui¹, Bin Zhu²,

¹School of Mechanical Engineering, Xi'an University of Science and Technology, Xi'an, Shaanxi, 710054, China
²School of Mechanical Engineering, Changan University, Xi'an, Shaanxi, 710054, China

*Corresponding author’s e-mail:632861682@qq.com

Abstract. In view of the current situation of serious dust over limit and low intelligence level in the integrated excavation face, combined with the smart control device of wind flow developed in the laboratory, an intelligent control system of wind flow in the integrated excavation face is developed based on the Internet of things technology. This paper presents the realization method of the system hardware and the development process of the software. The system collects the sensor signals and remotely transmits data from the intelligent control device for the wind speed, gas, dust and wind current at the fully mechanized working face, and the remote transmission of data. The device performs automatic control to achieve real-time regulation of dust movement. Finally, the software and hardware system is applied to the intelligent adjustment test platform of local ventilation equipment in coal mine for testing. The test results show that the system runs smoothly, the data is accurate and the operation is simple.

1. Introduction
Coal dust is one of the five disasters in coal mine, which will not only cause coal dust explosion, but also bring serious occupational hazards. The number of deaths due to accidents in coal mines is decreasing year by year, but the number of deaths caused by occupational health and safety environment does not decrease, but exceeds the number of deaths due to coal mine accidents[1]. In terms of research on the construction of occupational health and safety supervision information, at present, scholars are more focused on occupational health inspection management, occupational health archives management, occupational health report management, occupational health evaluation and other aspects to achieve occupational health and safety-related issues. The data are analyzed by statistics and simple analysis. These studies mainly focus on after-the-fact and in-event management. They lack pre-control of occupational health and safety, use traditional computer technology and Internet technology, and do not fully utilize coal mine smart mines and Internet of Things technologies[2]. The Internet of things technology provides a new idea for the environmental management of coal mine excavation face. Based on the monitoring and control of wind speed, gas and dust concentration exceeding the limit, this paper USES the three-layer structure of Internet of things technology to establish an intelligent air flow control system, so as to improve the working environment of workers in the comprehensive excavation face to reduce the probability of dust explosion accidents and the probability of workers' occupational diseases.
2. Overall architecture design of the Internet of things system for dust migration control

The Internet of things occupies a very important position in modern information technology, it is not only an important part of a new generation of information technology, but also the "information age" in the development of an important period, is referred to through information sensing device, according to the contract agreement, to any object connected to the network exchange information through the medium of information dissemination and communication, in order to realize intelligent identification, location, tracking and regulation, and other functions. It can quickly set up the network system and information collection and feedback. The industrial Internet of things system is mainly composed of the perception layer, the transmission layer and the application layer. This paper applies to coal mine comprehensive tunneling face daily production, the perception layer is mainly composed of gas, dust, and wind speed, distance sensor node modules, fixed point within the comprehensive tunneling face roadway layout gas, dust, and wind speed, distance sensor nodes, sensor nodes roadway in real-time data acquisition and real-time data using ZigBee and GPRS technology through gathering node transmission first machine system, PC system through the analysis of large amounts of data within the perception of roadway wind flow field real-time transport situation, Then, the air flow intelligent control device is controlled by the automatic control system to change the distance before and after the device, the change of Angle and the size of aperture opening and closing to change the dust migration in real time.

Between sensor node USES the star topology network connectivity in the form of the master node is gathering node device adopts full function, is responsible for organizing ZigBee wireless network, the node that ordinary sensor nodes using simplified function devices, is responsible for adding ZigBee wireless network and will collect information transmission of gas, dust, and wind speed, distance to the node. The aggregation node packages the data, and the GPRS module sends the packaged data to the host computer system with fixed IP address address. The host computer system realizes the display and processing of the data as well as the automatic management of the air flow intelligent control device. The overall system architecture is shown in figure 1.

![Figure 1 Full-scale excavation flour dust movement control system architecture](image)

3. Wireless sensor node design

Wireless sensor nodes are connected with each other using simplified functional devices and ZigBee wireless network technology's star topology. The star topology structure can meet the demand of increasing the number of sensor nodes with the increase of tunneling distance because of the small number of sensors arranged in the roadway and the short transmission distance.

3.1 Hardware design

The wireless sensor node is mainly composed of sensor, ZigBee module and power module, etc. The core processor of ZigBee module adopts CC2530 chip, and the sensor includes wind speed sensor, dust sensor, gas sensor and distance sensor. The data acquisition module converts the wind speed, gas, dust and distance analog signals output by the sensor module into digital signals through the A/D conversion module, which are processed by the core processor CC2530 and then transmitted to the
wireless sensor network sink node through the RF RF transceiver module. The hardware structure diagram is shown in figure 2.

![Sensor node hardware structure diagram](image)

![Wireless sensor software process](image)

3.2 Software design
Wireless sensor nodes are responsible for data collection and require nodes to automatically join the ZigBee wireless network. The program implementation is shown in figure 3. Firstly, the sensor node is initialized, parameters of the sensor node of wind speed, gas, dust and distance are set, and the ZigBee network is automatically joined. After the completion of data collection, if the timer has set the acceptance time, the packet forwarding will begin; After the completion of the next data collection work.

4. Sink node design of wireless sensor network
The sink node adopts full-function equipment. The sink node packages the data and USES the embedded GPRS module to send the data to the host computer with fixed IP in the way of IP addressing, so that the client can view and process the data and complete the monitoring and application of the target.

4.1 Hardware design
The aggregation node takes arm-linux embedded as the core. The ARM core processor is a risc-based microprocessor launched by ARM company, which has the advantages of stable performance and high reliability. Linux is an operating system running on ARM, which has many advantages compared with other embedded operating systems such as VxWorks, WindowsCE, pSOS and Neculeus. S3C2440 chip is selected as the core processor to connect the peripheral ZigBee module, GPRS wireless communication module, power module, etc. The design structure diagram is shown in figure 4.
4.2 Software design

The wireless network sink node is responsible for collecting the data collected by the sensor node, processing it and then packaging it and sending it to the remote host computer system through the GRRS network. At the same time, the sink node of the wireless network can also receive the instructions from the remote host computer system, and after the protocol conversion, it will be assigned to the corresponding sensor node through the ZigBee network, and the corresponding sensor node will perform the corresponding operations. Firstly, the hardware and protocol stack of air flow, gas, dust and distance sensor nodes are initialized, and the ZigBee network is established by the ARM core processor. Then, configuration information is sent to scan the surrounding wind speed, gas, dust and distance sensor nodes for matching. After matching, data are accepted and sent. The program implementation of the wireless network sink node is shown in figure 5.

5. Design of upper computer software for dust migration control system of Internet of things

The upper computer software of the system is developed by kingview software and runs on the Windows 7 64-bit operating system. The functions include the display of real-time data such as wind speed, gas and dust, the display of motor state in various parts of the air flow intelligent control device, the display of device automatic regulation interface, and the realization of data storage. The main interface is shown in figure 6.
The main interface is composed of real-time parameters of each motor of the air flow intelligent control device, data display of sensor collection, automatic interface and data interface. The automatic interface includes the motor control panel of the air flow intelligent control device, the simulation demo version, the numerical display box and the start and stop buttons of the air flow intelligent control device. See figure 7. The data interface contains three functions: data record, report query and report save. See figure 8.

6. Experimental verification
In order to verify the feasibility of various functions of the developed Internet of things system for controlling dust migration on aggregate excavation surface, the system was applied to the experimental platform established by our research group for testing. The dust concentration test data of respiratory zone height at the driver's position and pedestrian's respiratory zone height in the roadway were taken for regulation verification, and the data display was shown in figure 9. As can be seen from the figure, the dust concentration at the height of personnel's respiratory zone was significantly improved after the regulation. The maximum dust concentration at the height of personnel's respiratory zone was reduced from 1490mg/m3 to 877mg/m3, and the maximum dust concentration at the height of driver's respiratory zone was reduced from 697mg/m3 to 407mg/m3.

7. Conclusion
Based on the three-tier architecture of the Internet of things, this paper proposes an intelligent air flow control system based on the technology of the Internet of things. Through this system, the data of the integrated excavation environment can be uniformly analyzed and stored, and then the device can be real-time regulated by the upper computer to change the air flow state of the integrated excavation. Compared with the traditional method, this system has the advantages of wider monitoring range, higher monitoring accuracy and more complete system. In addition, it can collect a large amount of data for storage, so as to provide sufficient advance conditions for future research on incremental regulation rules, prediction and early warning and other big data directions.

Figure 7 System automatic control interface  
Figure 8 System data interface  
Figure 9 Effect of Fully Excavated Flour Dust Transport Regulation System
Acknowledgements
The author would like to acknowledge the support of National Natural Science Foundation of China (51874235), Industrialization project of Shaanxi Provincial Department of Education(18JC021)

References
[1] Liu H B, Li C H. Research on occupational health and safety management information system in intelligent mine [J]. Coal Science and Technology, 2019, 47(03): 87-92.
[2] Lei Y, Zhao S H. Research on Occupational Health Monitoring Information System Based on Cloud Service [J]. Practical Preventive Medicine, 2014, 21(08): 1021-1022+1012.
[3] Duan J. Research on Digital Farmland Information Monitoring System Based on Internet of Things Technology [D]. Qingdao University of Science and Technology, 2018.
[4] Jiang Y. Intelligent water and fertilizer integrated machine control system based on internet of things technology [D]. Qingdao University of Science and Technology, 2018.
[5] Gong X Y, Zhang X Y, Xia Z X, et al. Adjustment for the Optimum Distribution of Dust and Gas in Fully Mechanized Heading Face [J]. Applied Ecology and Environmental Research, 2018, 4985-5003.
[6] Gong X Y, Jia C C, Sun K, et al. Distribution Law and Prediction Model of Dust Concentration under Airflow Adjustment in Fully Mechanized Heading Face [J]. Mathematical Problems in Engineering, vol. 2019, Article ID 6210704, 2019.
[7] Wang S. Design of Elevator Building Fault Monitoring System Based on Internet of Things Technology [D]. Nanchang University, 2019.