Wireless Control System Design for Mine Rescue Robot

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Abstract — In mine accidents, unstructured environment is likely to occur. The rescue robot controlled by mine wireless telemetry and remote control system can improve the success rate of rescue in mine accidents. The system combines wireless network technology, automation technology and integration technology, and adopts star network structure. It can control multiple robots simultaneously, and has the characteristics of integration and intellectualization. The system robot used in mine unstructured environment rescue can avoid the injury of rescuers and improve the success rate of rescue.

1. Introduction
Many major safety accidents in mine operation directly lead to economic losses and casualties. After safety accident, the site of accident is prone to an unstructured environment with potential safety hazards. It may cause injuries to the rescue workers. The use of rescue robots can reduce personnel injuries, and the robots can also do the things that rescue worker cannot do.[1][2]

The rescue robot [3] can take the place of rescue worker and carry the detection equipment into the accident site to detect the post-disaster environment and transport relief materials. By the mechanical arms and fire hydrants installed on the robot [4], it is also possible to perform tasks such as opening and closing valves, removing obstacles, and extinguishing fires. The robot can complete tasks in damp heat and radiation and other complex environments.

At present, there are two control methods for rescue robots. One is wired measurement and control system [5], which uses computer as the measurement and control means, and wired cable as the data transmission tool to complete the measurement and control task. The second is wireless telemetry and remote control system, which uses microcomputer as the measurement and control means, and radio communication as data transmission tool to complete the measurement and control task. The first method uses computer and automatic control technology, which integrates the robots into system management, and achieves mutual cooperation and operation. Since the wired method may have circuit problems, it is difficult to control in unstructured environment, and has large investment. The wireless remote control system is more closely integrated with the mechanical structure, and the wireless penetration and stability are higher. How to install the wireless control system on the mine rescue robot is of practical significance.

2. System Introduction
The wireless telemetry and remote control system for rescue robot is a C/S mode system. It consists of a server as the dispatching side, and several rescue robots as the actuating sides. The dispatching side is used for communicating with multiple remote decentralized actuating sides in a wireless way, so as to realize the normal operation and collaborative operation of the system. The system integrates automation, wireless and other integration technologies.
2.1. Function design
The server side is designed to control objects in a certain area, and is used for system dispatching and management, sending signals to the actuating sides, receiving feedback information from the actuating sides, and performing parameter design, user management, actuating side upgrade and other functions. The actuating side combines with the rescue robot to control the action of robot by the command signal sent by dispatching side. According to the current state of robot, the feedback can be sent to the server side, such as coordinates, voltage, state, temperature and so on.

2.2. Hardware configuration and operation steps
The system sets the dispatching side consisting of server or desktop, wireless data transmission device, printer and high-gain guide grid antenna. The actuating side set as a main board, which is composed of wireless receiving device, micro control unit, temperature sensing device, and robot control unit. The wireless data transmission equipment includes battery, charging controller, solar panel, and DTU. It is equipped with a standard RS-232C communication port [7] and an RS485 interface [8], which can be connected to the server. The system is switched into automatic operation mode and manual operation mode.

In the automatic operation mode, the rescue robot can automatically collect the surrounding terrain and related data without manual intervention, transmit the data back to the dispatching side through the wireless transceiver unit, and judge the path according to the terrain. In the manual operation mode, the rescue robot can control the actuating sides in a certain area or single actuating side by sending commands through the server.

The bottom implementation of transmission and reception of the wireless commands is carried out in the form of data stream. The B/S terminal communicates according to the system communication protocol, and the commands are compiled into the bottom language through the computer, and then the signal is sent to the actuating side through wireless transmitter and antenna. Reception is opposite to the above steps. The actuating side uses the broadcast network. After receiving the signal, it will judge whether the signal commands itself and then select to implement the commands or not.

3. System design
The system design can be divided into communication network design, data transmission machine design and software design.

3.1. Communication network design
Because all command transmission and data transmission between dispatching side and actuating side are completed by radio communication. In order to accomplish these tasks, all data transmission devices of the actuating side need to be set in the wireless communication network, working in the form of communication. The design of radio circuit is the key point. Land mobile communication using VHF and UHF bands [9] is mainly transmitted in space waves, which are greatly influenced by terrain and surface features. Radio waves are generally the superposition of direct wave and diffracted wave, reflected wave and scattered wave which vary with time and space, so that the received signal has complex fading characteristics, including long-term (slow) fading caused by shadow effect of the barriers, and short-term (fast) fading caused by multipath propagation, which makes it difficult to predict the field strength. We use the method of theoretical calculation and field measurement to calculate the field strength. The field strength prediction models [10] include Bullington model, Egli model, Okumura/Hata model and so on.

3.2. Design of wireless data transmission device
MDS wireless data transmission device adopts the integrated design of DSP, forward error correction coding, software radio, digital modulation, coherent demodulation, Viterbi decoding, balanced soft decision and surface mount to provide high performance, high reliability and high stability of the device. It can provide standard RS232/RS485 interface and can be directly connected with PLC, RTU,
and industrial computer. The 25KHz channel spacing data transmission rate is 19200bps, the 10^-6 error sensitivity is -111dBm, and the transmission and reception conversion time is within 7ms. Considering the specific characteristics of wireless data communication, it has added technical measures to ensure that data codes cannot be lost when transmitting data and receiving data. Taking into account that the whole system is a multi-machine system, it also adds the response timeout and sending timeout alarm function to ensure the stability of the system. In addition, the data transmitter also has self-detection function, which can detect the signal path of the modulation state and demodulation state without external signals, and provides convenience for judging malfunction of the modem.

3.3. Software design

3.3.1. Server software design
Server side is used for control, output and human-computer interaction, so C# language which better laps with the bottom layer is adopted in the design. The design principles are as follows: conforming to software engineering, good human-computer interaction interface, good stability, and strong compatibility.

3.3.2. Actuating software design
FDD-Frequency Division Duplexing is mainly used for the actuating side. The programmable controller is adopted for data receiving, sending and judging while controlling the operation of robot. It can realize data storage and emergency recovery.

3.3.3. Communication protocol and message processing
Data transmission adopts MODBUS protocol, which is easy to deploy and maintain, without copyright requirements, and has no restrictions on modifying bits or bytes.

4. System anti-interference measures
The rescue robot is mainly used for post-disaster rescue, so there is high stability requirements on the system. Especially in the case of one-to-many control, the orderly operation and emergency measures can be realized from the following aspects:

4.1. Hardware

4.1.1. The frequency is 223–226 MHz as specified by the Ministry of Industry and Information Technology. This frequency range is less used and has less interference.

4.1.2. Transmitting and receiving devices are produced by well-know brands.

4.1.3. The field strength communication standard is 4-level standard.

4.1.4. Adopt frequency shift keying modulation, in which the circuit adopts single chip control mode.

4.1.5. The communicator interface is processed by special circuit in order to maintain optimum value of the interface level during conversion.

4.2. Software

4.2.1. The communication between dispatching side and actuating side uses MODBUS communication protocol.

4.2.2. All data transmissions have coding error correction.
4.2.3. The important commands are sent by redundancy technology. In addition, the lightning protection of system and the transmitting and receiving time between dispatching side and actuating side must be considered.

5. Conclusion

5.1. Wireless rescue robot is more flexible than wired robot. In unstructured environment, the wired robot cannot cross and arrive some of the accident sites, and wireless robot has larger movement area.

5.2. Wireless rescue robot can move farther. Wired robot is restricted by the circuits, and wireless robot has a farther movement area.

5.3. Through system composition, two robots can achieve better cooperative rescue operation.

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