Multifunctional Miners Helmet Design based on Wireless Sensor Network Technology

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Abstract. At present, domestic coal mine safety monitoring mainly realize the function of downhole data acquisition, such as the collection of gas, wind speed, temperature and other data.But the down hole data is not in full organization, use and manage on the inoue, meanwhile coal mine has the shortcoming of not flexible safety equipment , high defects of integration . This article design with three major functions : real-time monitoring of gas, precise positioning, lighting the of the miners helmets and PC (including the PC and the mobile terminal) monitoring systems. Taking miners helmet as the carrier, erected precise positioning systems and gas real-time monitoring system based on the acceleration sensor MPU6050 and meter step algorithm , we propose a suitable mobile node (Donetsk) more topologies, and by moving the nodes and fixed nodes signal transmission network to the monitoring center . This work test result shows that miners positioning error is less than 3m and gas monitoring systems , lighting function properly.

Research Status

China is the world's largest producer of coal, accounting for 31% of world production. While China's basic coal as an important energy and materials, occupies an extremely important strategic position in the national economy. In China's energy structure, coal accounts for 70% of China's primary energy production and consumption structure , and it will continue to be China's major coal energy in a fairly long period of time. Coal-dominated energy structure in the short term is difficult to change. However, compared with countries in the world, China's major coal-producing coal mines not only has more complex geological structure, mainly to underground mining, but also has more serious natural disasters. In recent years, China's coal mine accidents occur frequently, not only causing economic losses but also caused heavy casualties, the security issue has become the bottleneck of coal production. Statistics show that China's coal mines one million tons mortality rate is 100 times of the United States ,10 times of India's and economic losses caused in developing countries production safety accidents reached more than 2500 billion yuan .

Multifunction helmet design

The overall design

Miners helmet is designed with three functions: a real-time monitoring with a gas, precise positioning, lighting ,which can effectively improve mine safety. By MPU6050 for accurate positioning, and uses the Java language PC software for mobile terminal, serial communication PC side. Central control module of the helmet is STM32F051R8 and the power supply is 3.3V. STM32F051R8 collected information of X axis, Y axis, Z axis in acceleration sensor , and information about gas concentration gas sensor then transmitter via the RF module; sensor awaken or off mode selection is configured through STM32's I / O port.

Hardware Design

Power Design

Using 8.4V-0.5A constant current charger to supply Section II Lithium battery,with the output 7.4V by LM2596 regulator module and output 5V supply AMS 1117 regulator module and gas sensors and MPU6050 six-axis acceleration sensor, AMS1117 regulator module output 3.3 V supply

GPS module and STM32. When the miner charge the helmet , they only need to connect USB charging interface,which is simple and convenient.

Miner's lamp design

Traditional lamp is removable products, the miners can fix it on the helmet or take it hand according their wishes and working conditions,cause the traditional lamp power generally use acidic or alkaline solution as the electrolyte of the battery, so carry around and inconvenient, but also may cause trouble for the work. Our reservation can be written in a miner's lamp removable advantages, but also has been transformed following two aspects.

1). Design uses high-energy density lithium polymer battery as a power source, and used battery overcharge and over discharge protection circuit to manage, ultra-high brightness white LED as a light source.

2). According to the brightness of the environment, adjust the brightness of light, energy saving.

3). Designing a rotary lamp base, the miners can adjust the angle of lighting according to need to work to use more convenient and flexible.

Software Design

Gas Monitoring System

Currently gas detection on the market only has the gas monitoring alarm function, mine management personnel can not have timely access to underground gas situation, and thus can not eradicate the problem of the miners in the gas overrun situation is still illegal job. Therefore, we propose a method of gas detection technology with wireless communications technology combined with a gas gauge signal radio transmission multi-function miners helmets, solve the problem of the original signal can not be acquired alarm monitoring center, the same time with the helmet mobility, to realize mobile monitoring gas to make up for the lack of fixed gas monitoring, so as to enhance the monitoring system for mine gas monitoring capabilities.

This design uses MJC4 / 3.0L catalytic combustion of methane sensor. MJC4 / 3.0L type catalytic element work according to the principle of catalytic combustion effect by detecting component boxes compensation element pairs by two arms of the bridge, the case of combustible gas detection element resistance is increased, the bridge output voltage change, the voltage variable increases in direct proportion with the gas concentration increases, the compensation element from the reference and temperature compensation effect.

Because the output voltage MJC4 /3.0L is too small to meet the requirements of STM32F0. We need to amplify the output signal of MJC4 / 3L . Signal amplification achieved by adjusting the gain control voltage amplifier AD602 .

Communication System Design

Considering the depth of the metal content, miners mobility mine, we achieve information transmission by passing the wireless sensor network technology. Mobile node (Donetsk) will take the form of a broadcast transmission of information to the nearest fixed nodes, fixed nodes and then to transfer the information transmitted via a multi-stage fixed to the central node, and finally the central node via a cable to transfer information to a monitoring center.

Internal RF module has five registers: the status register, the configuration register, transmit address register, transmit data registers and receive data registers. In addition to reading and writing to the register, the need to switch the RF module's operating mode can be controlled. RF module and control core connection shown in Figure 1.
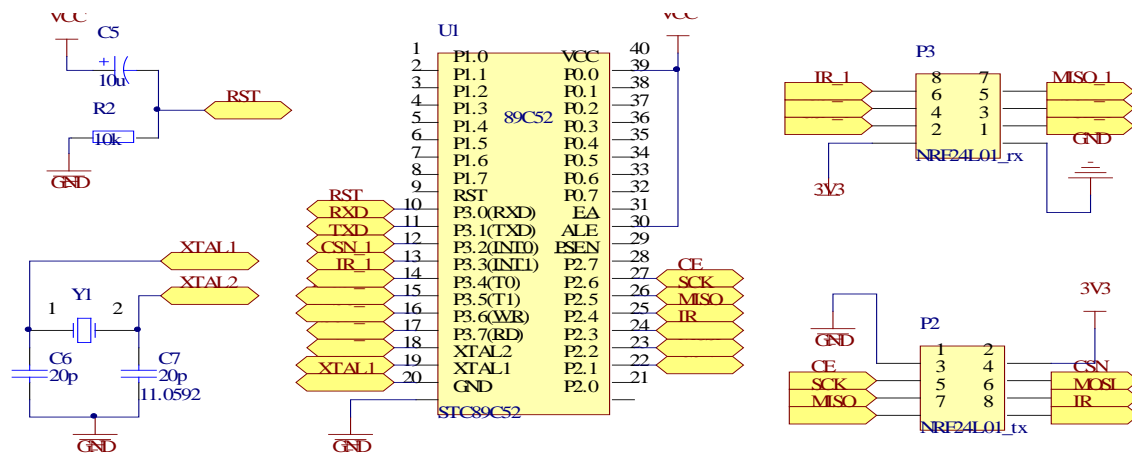
Fig. 1 Connected graph of the RF module and control core STM32

1). Frequency selection

The main interference in the confined space is the reflection of the radio wave and the energy attenuation caused by the reflection of the radio wave. Therefore, the choice of the frequency of the wireless communication is directly related to the communication effect. According to the data, the best frequency of wireless transmission is 400~ 900 MHz, and in this band, the attenuation becomes smaller and the transmission distance increases with the increase of frequency. Therefore, the selection of the 900 MHz band used in the mine wireless communication.

2). Anti collision technology for wireless communications

In order to avoid the same place at the same time the alarm signal is generated in several miner's collision, the collision technology software. Its principle is when a miner's lamp need to launch overrun signal, the first into the monitor mode, to determine whether the received carrier, if did not receive the switch to transmit mode emission signal, otherwise wait, until the detection not to carrier so far.

3). Data receiving technology

Carrier detection: when the RF module works in the receiving mode, if there is a carrier with the same frequency as the RF module, the carrier detection CD pin is set high in order to avoid collision with different transmitter data at the same frequency. When the RF module is ready to transmit data, it should enter the receiving mode first, determine whether the default channel can output data.

Address matching: when the RF module is working in the receiving mode, the packet address is introduced to the same address matching (AM) pin set high, which is used to indicate that the RF module is receiving a number of data ready and the signal is high. If the data is ready and the signal is not high, such as the CRC error, the AM pin is at the end of the data packet, and the location is low.

Automatic repeat: in a noisy environment, improve the reliability of the system in a way is a duplication of packets sent several times. The characteristics of the RF module with automatic retransmission. O _RET RAN AUT bit, as long as the TRX and TXEN remain high, the circuit will continue to send the same packet. When RX T is low, the RF module is converted to the standby mode after the RF module is currently being transmitted.

Design of the positioning system and the upper computer

For workers who work in the mines, once they are in danger, the position of the miners is very important. The accurate positioning of the miners and transmit the information to the monitoring center, showed overall distribution of ore miners in hole in the upper machine, so that the accident happened, timely and accurate search and rescue.

First, through the U-BLOX module NEO-7M GPS to determine which coal mine is from the hole into the hole, then you can know the starting position of the miners, after entering the mine hole, will be the blind area of GPS, so after entering the mine hole with an acceleration sensor MPU6050 X, Y, Z three axis acceleration and angle. According to the deviation of the X axis, Y axis, Z axis angle can determine the direction of the people. X,Y,Z three axis acceleration change to the people's walking, looking up, turning around and other different attitude .You can identify the walking pace, according

to the formula: distance = step length correction factor *step length * step number determining the distance of walking. After receiving the data from the upper computer, it is shown that the direction of the person is judged by the angle of the upper computer, and the distance of the walking distance is calculated,

The core of the GPS module uses the NEO-7M module of UBLOX, with 50 channels, the tracking sensitivity is -161dBm. MPU6050 acceleration sensor, which can realize the data of acceleration, angular velocity and angle in three aspects of the space in the dynamic environment, which can be achieved in the dynamic environment.

In order to facilitate the monitoring center at any time to grasp the mine hole, this paper uses the Javascript language to write the upper computer software, realize the serial port communication between the node and the PC, the mobile phone and the real-time display, storage and graphics functions. The upper computer software includes serial data acquisition and processing, and serial display unit as an example, the data is transmitted to the upper computer, which includes the frame head and frame tail.

On the right side of the upper computer interface is the exact position of the miners in the coal mine. A safety helmet is on behalf of a miner,when the miner moves,the hat on the upper computer will move.The left is the monitoring of gas, once the gas exceeds the standard, it will appear red, and in the upper left corner coordinates. Taking into account the monitoring staff will sometimes leave the monitoring center, we have developed a mobile terminal monitoring software to facilitate the monitoring of personnel time

Experiments and analysis

Lamp property test
In order to understand the miner's lamp performance, we test the miner's lamp on the use time of the in a number of different brightness file , miner's lamp is divided into four stalls, the use of time were 10h, 15h, 21h and 29H. The lamp in the normal power frequency voltage under the full power of the average time is 4.8h.

From the above tests, all the test data are less than the real value. This situation is caused by the fact that the step size and the correction coefficient of the program are not consistent with the actual. In mine rescue work, complex ore cave rescue channels up to hundreds of meters. Therefore, we think that the works of the error is within the acceptable range.

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Rotation angle accuracy test
Group testing, the work was 90 degrees, 180 degrees, 270 degrees, 360 degrees. The error of the measurement is compared with the real angle of the upper computer and the angle is measured by the test. Every angle measure 10 times, finally take the average value. At 90, the average value was 89.24, and the difference was 0.76, and the average value was 174.30 at the 180 degree, and the difference was 5.70 at 270, and the difference was 5.88, and the difference was 7.12.

Gas monitoring and alarm testing
To test if methane gas exceeded with gas tank, before not spray methane gas(under normal circumstances) , the upper computer does not appear red alert, buzzer above the miners cap will not ring. When we finished spraying methane gas, upper computer methane gas comes out red alert,buzzer above the miners cap beeps.
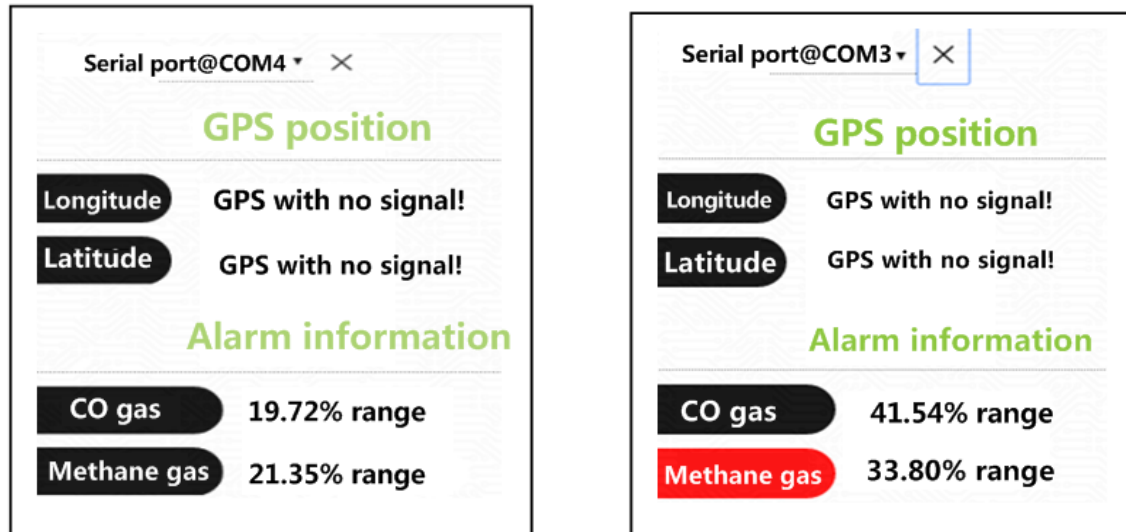
Fig. 2 Stable left upper computer interface before testing; Stable right upper computer interface during testing

Conclusion

This article designed positioning algorithm based on the acceleration sensor MPU6050 .Compared with the domestic RSSI (Received Signal Strengt Indication) positioning algorithm, this device has the features of low hardware cost and being easy to operate . The device has the following advantages:

1). Considering the depth of the mine, metal content, miner's mobility, we design a mobile node (Donetsk)and transferring it to the nearest fixed nodes in the form of radio information ,then fixed nodes transmitted to the central node topology via a multi-stage information.Compared with other topologies,it reducing the transmission path, saving energy, enhancing the miners helmet endurance.

2). Most wearable products on the market are used to detect the signs, the elderly drop, blind navigation. But few people will use wearable devices in special industries.This article will apply it to miners helmets,so that the original single-function helmet is upgraded with three functions such as precise positioning, gas monitoring and lighting,building up a miners helmet RTLS and gas monitoring system.

3). The current protective devices need to additional wear on the basis of the original miners clothes and helmets ,during the using course will have a negative impact cumbersome and troublesome workers. Multifunction helmets can effectively improve the status and improve work efficiency.

4). The device can play the role of prevention and monitoring of mine . It can quickly locate the miners when the mine accident happens ,to shorten rescue time, reduce mine deaths and improve mineral production safety.

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