Discussion on Application Technology of 5G Network in the Field of Coal Mine Robots

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Abstract. In this paper, the technologies of obstacle-surmounting performance, explosion-proof design, communication and sensing of robots are researched and explored, and the prototype of inspection robot body and handheld remote control terminal are developed. Through the combination of virtual simulation, theoretical calculation and field test feedback, the modular design and optimization technology of robot scale, structure and function is broken through, and the modular special robot for mining with strong environmental adaptability is developed. This scheme is suitable for large-scale popularization in coal mines.

Keywords: 5G network, Artificial intelligence, Explosion-proof safety, Monitoring and control, Structural topology.

1. Introduction

Looking back on the history of 5G, we all know that the communication technology is updated every ten years. From the first generation of communication technology to now, the wind is surging and the influence on people is deepening day by day. The so-called: 4G changes life, 5G changes society, and scientific and technological progress is closely related to us. 5G has brought about the Internet of Everything in the whole society, which has greatly promoted new applications and new business models. At the same time, AI is also an important direction for robots. In the future, a large number of data calculations will be processed in the cloud. In the future, computers will only have a monitor and a mouse, and a large amount of information processing will be put in the cloud, and robots will also put their brains in the cloud. Then the data exchange between the brain and the actual controlled object, or between the brain and various parts of the robot body, requires a high-speed communication mode. In addition, the actual working conditions require QoS and DDS technology, which proves that 5G is the inevitable trend of productivity development. Therefore, 5G, the fifth-generation communication technology, is especially suitable for the combination of robot and AI.

When we were working as a 5G robot, we integrated the 5GCPE module of Huawei into the robot equipment. This module can communicate with the 5G micro base station on the spot, and then transmit the signal to the 5G core backbone network, and transmit the signal to the control room of the mining area through the cloud server. The on-duty personnel can use the 5G robot to monitor the operation of all equipment through the Internet. The whole system includes various signals based on 5G, a series of
equipment at the control end and the construction end, which constitutes a 5G+ robot intelligent inspection system for belt conveyor [1].

2. Overall design scheme of 5G robot

Figure 1 shows the overall design scheme of the robot. In this paper, field investigation, theoretical calculation, numerical simulation, experimental test verification and other research methods are combined, and the knowledge of mechanical design, robotics, heat transfer, robot structure topology optimization, mine equipment reliability theory and test technology are comprehensively applied. Taking the coal mine safety control dangerous gas inspection robot as the main research object, the robot obstacle-crossing performance, explosion-proof design, communication and sensing technology are researched and explored, and the inspection robot body and handheld remote control terminal prototype are developed. The mechanical components such as the driving system, suspension system and actuator of the robot are specifically developed, the hardware circuit is designed, the software system is developed, and the servo drive system, wireless control module and video acquisition system are selected and debugged. Carry out performance test, improve the design, prepare process documents and obtain explosion-proof certification.

![Figure 1. The overall design of the robot](image-url)
In view of the extremely severe working conditions such as complex terrain, easy corrosion and explosion in the coal mine field, and considering the possible influences of temperature/humidity field and pressure field on the mobile chassis of the robot, a special inspection robot for mine is researched, which can adapt to the harsh environment of the operation site, realize high walking throughput, high operation reliability and meet the national standards for explosion-proof performance. In the process of robot development, according to the failure mechanism of its operating system, the system protection and performance reinforcement technology are studied; the static and dynamic mechanical analysis is carried out combined with the overall stress and strain distribution of the robot; the modular design and optimization technology of robot scale, structure and function is broken through by combining virtual simulation, theoretical calculation and field test feedback, so as to develop strong environmental adaptability Modular mining special robot [2].

3. Demonstration of core key technologies in the design process of 5G robot

3.1. Design of walking mechanism for robot with high manoeuvrability and obstacle crossing ability

Because the robot has poor obstacle-crossing ability, it can't go deep into the complex underground area to complete the inspection task. The underground roadway in coal mine is narrow, with rails, transportation belts, cables and pipelines crisscrossing, and the terrain such as steps, gullies, puddles and "going up and down the mountain" is complex. Coal, cinder, waste rock, tools and other sundries are everywhere, especially the roadway after extreme disasters is more complex and diverse. Therefore, robots need to have high maneuverability and strong obstacle-crossing ability. Coal, waste rock, coal cinder and coal slime are easy to enter or adhere to the track, which is easy to get stuck for the common track structure, but it is difficult for the common wheel structure to climb over larger obstacles. Therefore, in order to meet the requirement that the robot walking in such a complex mine environment still has good motion ability, it is necessary to design a walking mechanism with good terrain adaptability and strong obstacle-crossing ability, which is a key technical problem.

3.2. Design and implementation of explosion proof robot system

If the explosion-proof problem of the robot is not solved, the robot cannot be used in the well. Therefore, in order to make the robot perform the tasks of patrol inspection and detection in the dangerous areas underground, it is necessary to solve the explosion-proof design problem of the robot first, make it meet the explosion-proof requirements stipulated by the national industry, and obtain the coal mine safety standard certification. The explosion-proof design of robot needs to solve the explosion-proof design problems of robot mechanism, electrical, control, communication, power supply, sensors and other components one by one. This will cause the increase of the overall size, volume, weight and power capacity of the robot, and then affect the walking and endurance of the robot. Therefore, the explosion-proof design and implementation of robot system is one of the key technical problems, which must be solved emphatically.

3.3. Underground complex environment communication technology

If the communication problem of the robot is not solved well, the robot will not be able to transmit the environmental information of the inspection area back to the hand-held terminal of the inspection personnel, and it is also difficult to realize the robot's deep advance in the underground. Therefore, it is necessary to solve the problem of communication and transmission of data and image signals by robots. However, due to the narrow tunnels in coal mines, most of them are pipeline-shaped, multi-bend structures and coal seams which strongly absorb communication signals. This makes the transmission of communication electromagnetic waves in the underground much more difficult than on the ground. Whether the robot can detect and return the environmental information in the unknown hazardous operation area or meet its own needs, it must be based on the data communication interaction between the robot and the upper computer. Therefore, downhole communication is one of the key technical problems. The problems are mainly reflected in what kind of wireless communication technology to use,
how to overcome the absorption of wireless signals in roadways, how to release wireless nodes by robots to make wireless signals self-organize networks, and how to design wireless nodes with small size and high transmission power [3].

4. 5G robot coal mine safety certification inspection

4.1. Safety standard type test
Safety standard type test is a series of tests that must be carried out for coal mine inspection robots to apply for coal safety signs, and its focus is on the safety performance and working stability of robots. It mainly includes 26 inspection items, such as appearance, electrical performance, power frequency withstand voltage, impact resistance, high and low temperature work, alternating damp heat and so on. Among them, the withstand voltage test and the internal ignition non-explosion test are unique to mine products, and these two tests are collectively called explosion test, which is the most important content of safety standard test. The explosion test is to put the robot explosion-proof box in an airtight explosion container for methane explosion test. During the specific operation, methane gas is introduced into the explosion container and the explosion-proof cavity, and the methane gas inside the box is detonated by the spark plug installed in the explosion-proof cavity, so as to test whether the strength of the explosion-proof box can meet the requirements, and at the same time, test its non-explosion transmission property—internal explosion does not cause explosion outside the cavity. The explosion test of the robot flameproof body is shown in Figure 2 [4].

![Figure 2. Explosion test of the main body of the robot](image)

4.2. Structured terrain simulation and experiment
It is far from enough for coal mine inspection robot to only meet the safety standard type test. Safety performance is the premise of robot, but good motion performance is the guarantee of robot's patrol inspection. Therefore, it is necessary to test the motion performance of the robot.

The underground environment after the disaster is an unstructured terrain. In order to facilitate the simulation test of robot, it is necessary to abstract the unstructured terrain of mine into structured terrain. Therefore, the related test platform is developed, which is helpful to the initial research and development of robots. A typical mine terrain can be abstracted into seven structured terrains: flat road surface, bumpy road surface, ramp, track, single step, multi-step and trench. According to these seven terrains, the relevant test platforms are developed, as shown in Figure 3.
Different mines have different road surface parameters, so the developed test platform can realize the change of test parameters. On the bumpy road surface shown in (a), the height of the road surface can be changed from 80mm to 200mm, and the angle can be changed from 15 to 45. The slope shown in (b) can be changed between 0 and 35 according to mine requirements. (c) The track spacing of the track shown in (c) can be changed from 800mm to 1200mm. (d) It is a test platform for the mileage and heat of the robot. The robot is placed on the test platform, which can drive the belt to move, and the belt drives the idler to rotate. The resistance of the idler can be adjusted to simulate the cruising range of the robot under different resistances. At the same time, the device is equipped with an infrared thermal imager, which can observe the heating of the robot during long-time operation. The width of the single step shown in (e) can be between 100mm and 500mm, and the height can be changed between 50mm and 30mm. For the continuous steps shown in (f), the step width can be changed from 200mm to 300mm, and the height can be changed from 80mm to 200mm. (g) the width of the trench shown can be changed from 300mm to 600mm [5].

Tests are carried out on the robot's crossing track, bumping road, climbing continuous steps, crossing single steps, crossing trenches, climbing, wading, continuous walking and slime ground respectively [6] to test the performance of the robot, as shown in Figure 4. By testing, the highest performance indexes of the robot are obtained, as shown in Table 1.
Figure 4. Robot single performance test

Table 1. Single robot performance parameters

| Performance Parameter                          | Parameter          |
|-----------------------------------------------|--------------------|
| Maximum endurance                             | 5km                |
| Maximum operating speed                       | 1.5m/s             |
| Maximum uphill and downhill angles           | 30°                |
| Maximum height of upper and lower steps       | 250mm              |
| Up and down continuous step capacity (height×span) | (⩽150 mm) × (⩾280 mm) |
| Maximum crossing channel width                | 400 mm             |
| Water wading ability                          | 350 mm×10 m (Depth × length) |

5. Conclusion
At present, mining robots can put some computing power on the cloud through 5G technology. For example, robots monitor fireworks in mines, monitor equipment failures, and monitor personnel's violations, and transmit the acoustic, photoelectric, video and other sensor signals captured in the field to the cloud. Then AI calculation and big data analysis are carried out in the cloud, and a large number of personnel violations are also transmitted to the cloud for analysis through 5G, which effectively monitors personnel, environment and equipment and provides a basis for decision analysis.

In the future, 70% of the workforce can be replaced by intelligent equipment and systems, especially in traditional industrial enterprises, such as mines, which are typical energy enterprises. As we know, there are nearly five million employees in the coal mining industry, and they will be replaced by a large number of machines in the future. To control these machines, a reliable, strong, real-time, highly reliable and low-latency communication mode is needed, and 5G is the only way to solve this problem. In the future, if we want to ensure the personal safety of underground workers, workers must operate machines on the ground to mine coal. However, if the signal of shearer is delayed to the well, it is very dangerous, and the millisecond response of signal transmission on the well and underground must be guaranteed.

At the same time, the workers are liberated from the "bitter, dirty, tired and dangerous" environment through the inspection robot. In the past, without these technologies, workers could only work in the
environment of coal dust and noise. With the new technology, workers can sit in the monitoring room, wear suits and drink coffee to monitor all the equipment, and from then on, blue-collar workers become white-collar workers. Such revolutionary schemes and new methods are gradually becoming reality.

References

[1] Zhang Hui, Li Fengle, Zhao Haitao, etc. Wireless backhaul optimization algorithm in 5G dynamic heterogeneous scene [J]. Computer Engineering and Applications, 2020, 56 (16): 62 - 68.
[2] Guo Huijie. On the impact of 5G technology on the construction of mobile communication networks [J]. Science and Wealth, 2020, (7): 157.
[3] Zhou Yunli. Research on the Innovation of Library's Digital Reading Promotion Service Model from the Perspective of "AI+5G"[J]. Henan Library Journal, 2020, 40 (7): 101-102, 105.
[4] Zhang Xuefei. Research on the reform of teaching methods of environmental design under 5G mobile network [J]. Journal of Higher Education, 2020, (27): 133 - 135.
[5] Xiao Yu, Wang Shuai. Discussion on the application of 5G and MEC in the industrial Internet [J]. Post and Telecommunications Design Technology, 2020, (7): 7 - 11.
[6] Xu Runfang, Wang Yuqin, Zhang Bowen, etc. Six-degree-of-freedom life handling robot design [J]. Henan Science and Technology, 2020, (19): 8 - 9.