http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (24): 8135-8140, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.8135.8140

Research Status on Control System of Coal Mine Rescue Robot

Liu Jian, Ge Shi-Rong and Zhu Hua
School of Mechatronic Engineering, China University of Mining and Technology, Xuzhou, Jiang Su 221116, China

Abstract: The coal mine rescue robot is the device which replaces the rescue workers to detect the environment and rescue victims in mine. And the control system is the core of the coal mine rescue robot and decides the performance of the robot. To design the control system which meets the requirement of coal mine rescue, it is firstly analyzed that requirements of the coal mine rescue robot in this study. Then, it is recommended that the control systems of coal mine robots which have been developed in China and its advantages and disadvantages are analyzed. In the end, we suggest an open control system based on ether net which meets the requirements of the coal mine rescue robot. The outdoor test shows that this control system effective and reliability for coal mine rescue robot.

Key words: Coal mine rescue robot, control system, ether net

INTRODUCTION

The coal mine accidents have occurred because of the hostile environment and complex geological conditions. In the last decade, the coal mine accidents have reduced but it has taken place more than 1000 times every year. The robot has shown the great potential to assist in the rescue and search tasks. After the coal mine disaster, it is necessary to develop the Coal Mine Rescue Robot (CMMR) in according to implement rescue work smoothly and to reduce casualties but replaces the rescue workers entering the mine, to detect the environment and rescue victims(Sun, 2010). From 1990s, many countries, such as Austria and American, have research the coal mine rescue robot and some of the robots have been used in the coal mine rescue such as V2 (Murphy *et al*., 2009).

China is the major country of coal producers and its coal mine accidents is the most frequency, so, the research on coal mine rescue robot is very impotent for China. Since, 2006, the coal mine rescue robot has been developed by China University of technology and mining. Up to now, variety robots have been developed by different research institutions in china. But there is not one robot to meet the requirements of coal mine rescue.

Rescue robot is one of the hazardous operation robots (Li, 2003). To adapt the unstructured environment, the hazardous operation robots should be an intelligent mobile robot which has ability of environmental cognition, behavioral decision and move control. However, the control system is the core of the intelligent mobile robot to realize those functions in line with the command and the information from sensors Fan and Tan (1999). And it is in relation to the robot performance.

In this study, we analyze the requirements of the coal mine rescue robot firstly. Then, the control systems of coal mine robot at present are recommended and analyzed its advantages and disadvantages. In the end, we suggest an open control system based on ether net to meet the requirements of coal mine rescue robot.

REQUIREMENTS OF COAL MINE RESCUE ROBOT

To adapt the coal mine disaster environment, the factors of operating condition should be considered for the robot control system but includes load, assemble space, finite power, limited calculated performance and communication bandwidth.

The weight of CMRR should be as light as to be carried by rescuers. After the disaster, the electricity will be cut and the electrical equipment is turned off work. The tunnel is full of gas and water. The communication condition in mine is adverse to cause the wireless signal transmission attenuation and transmission power is limited. And wire communication will add the robot weight. The power only be supplied by battery pack and capacity is limited.

As the vital component, the control system must meet the following requirements to adapt complex circumstance:

- Low-power dissipation, small in size, light weight, high cruising ability

Corresponding Author: Liu Jian, School of Mechatronic Engineering, China University of Mining and Technology, Xuzhou, Jiang su 221116, China

- High integration density and scalability to realize mechanical-electrical integration easily and reduce the size of load. It is advantageous to shorten the development cycle and reduce development costs
- To use real-time multi-tasking system. Real-time system responses to dynamic change of the environment quickly and multi-tasking processing mode can make full use of computing power
- It is with functions of network communication to satisfy the collaboration of the multi-robot system

COAL MINE RESCUE ROBOT CONTROL SYSTEM ARCHITECTURE

At present, a lot of universities, research institutions and enterprises in China have developed mine rescue robot. But the control system architecture is different. Those are as follow.

Closed control system architecture based on IPC: This control system architecture is based on powerful functions compact structure high reliability IPC. And it is a system of centralized control which gathers the data through data acquisition card and drives robot motion by I/O.

In 2006 and 2010, the coal mine environment exploration and rescue robot CUMT-I and CUMT-II but is developed by the institute of rescue technology and equipment in China University of Mining and Technology, is based on PC104 IPC and adopts centralized control (Zheng *et al*., 2009). The IPC of CUMT-II robot collects the data of infrared switches, infrared distance measuring sensors, current sensors, voltage sensors and gas detect sensors by data acquisition card and reads the data of Inertial Measurement Unit (IMU) and electronic compass by RS232 comport. The robot avoids obstacle by analyzing the data from infrared switches and infrared distance measuring sensors. The heading and pose are sure by the data of IMU and electronic compass and the tack is calculated combining the data of encoders. The robot moves as the command from the remote control unite. The autonomous control program is based on the behavior control model and the performance of the autonomous navigation and avoiding obstacle can work.

In 2009, a type of four swing arms mine rescue robot is developed by school of mechanical engineering of Taiyuan University of Technology (Zhou *et al*., 2009). The robot control system is mainly composed of upper and lower. An IPC is used as the upper to display the robot and environment information in real time and the Embedded IPC is used as the lower but collects the robot and environment information, disposals of those data and autonomous positioning and navigation. Multi-layer software architecture is introduced in the software design. From top to bottom, it is the coordination and decision-makers layer, the behavior plan layer and the information fusion layer.

In 2009, The Chinese academy of sciences Shenyang automation and Institute of automation of Shandong academy of sciences developed a type coal mine rescue and search robot which employs combination control system of remote control and semi-autonomous control and wireless communication system (Hou *et al*., 2009). The robot controller is the PC104 IPC which captures the data and controls the electrical machine through serial port.

However, it is not flexible to layout because the IPC's hardware is fixed standard structure. The IPC power consumption is too high to release much heat but it is difficult to dissipate heat because of the sealing design for explosion proof and waterproof. The control system specificity is very strong and extensibility is not high because of closed architecture. If the function is changed, the control system should be designed again.

Distributed control architecture based on PLC: Because of advantage in openness and expansibility, the deliberating distributed control architecture is the perfect way to realize intelligent control. It is fit for unstructured environment modeling and path planning and conquers the uncertainty of dynamic change on moving by reactive behavior (Wang and Qu, 2002; Zhou *et al*., 1998). It has strong function and excellent flexibility.

Based on the performances of high reliability, easy to learn programming, small in size and strong extensibility, the CMRR distributed control system with PLC is developed by Institute of intelligent robots of Beijing Institute of Technology in 2010 (Gao *et al*., 2009). The control system also is broken down into remote control box and robot control system. The remote control box uses a PLC, a communicator, battery, power modulate, keyboard and stick. Five Panasonic FPÓ C32 micro PLCs form a distributed control system. They are linked by RS485 series line.

However, the real-time performance of PLC is not high and cannot progress multi tasks, so that intelligent control is not able to realize.

Distributed control architecture based on IPC: The coal mine detect robot developed by Robotics Institute of Harbin Institute of Technology and Tangshan open electric appliance co., LTD takes this control system. It is divided to robot control system and remote control box. The IPC is used as the core of the robot control system and motion control system, audio collection system and data acquisition system are linked by CAN bus (Wang, 2007).

The robot developed by Robotics Institute of Shandong University takes the NOVA8890M

PC104/PC104 Plus IPC as the core of control system and communicates by CAN bus. One of the controllers as a note of the CAN network combine the distributed control system. The program visits notes with Client-Server structure (Chai, 2007). Because of the IPC, this type of control architecture has the same heat dissipation and power consumption problem as the closed control system architecture based on IPC.

Distributed control architecture based on embedded system: Because the embedded system can be cut according to the application requirements for hardware and software and has low power consumption, it is taking place of IPC to meet the requirements of function, reliability, cost and volume.

Robotics Institute of Harbin Institute of Technology has developed a robot system which is made up with master robot and slave robot and its distributed control system based on wireless sensor network. The master robot realizes the features of motion, communication, collecting sensor data, data progress and video capture with the embedded IPC (Zhou and Li, 2009).

Because of the coal mine wireless signal attenuation and more large interference, the stability and reliability of wireless sensor network is low.

To sum up, the design of the mine rescue robot control system is developing to adapt the hostile environment in mine. Concrete analysis is as follows:

- The mine rescue robot control system is consisted of robot motion control system, data acquisition system, remote control box and communication system

Robot motion control system is in charge of motion, navigation and path planning. The information of gas and video is collected by data acquisition system. All of the models are linked by CAN bus or RS485 bus. The data from the robot is displayed on the screen of the remote control box and the command from the controller is send to the robot by the remote control box. The communication system supplies reliability and accuracy data link.

- The control system is developing from the closed architecture to the distributed architecture

Mine rescue robot is a type of the intelligent mobile robot. At present, deliberating/reaction compound architecture has become the main paradigm of intelligent mobile robot design. The distributed architecture is in favor of expanding control system, because Standard operating systems, control language and bus are used.

- The control core is being altered from IPC to embedded system

Embedded system suits the open development platform of the distributed control architecture. And it is scalable, low power dissipation and high reliability to meet the mine rescue robot.

- Control bus is from the RS232 bus or RS 485 bus to CAN bus

CAN bus is currently the only international standard field bus approved but has unique flexible design, good features and high reliability to be used in the distributed control system. As the embedded system support for Ethernet and the high throughput and speed of Ethernet, it is being used in the control bus.

CONTROL SYSTEM BASED ON ETHERNET

A distribution control system based on Ethernet is designed according to the advantage of the control system before and the development trend. This control system is based on Ethernet, so that it is to the benefit of mechatronics and take little space because of the high integration and scalable of Ethernet. The core is 32-bit micro-controller embedded systems which has high-performance and small in size so, as to reduce the weight of explosion proof shell. One is to control the robot motion and the other one collects the data of gas sensors. The real-time multi-tasking system takes full advantage of computing power to response dynamic environment quickly and to adapt the unmanned environment. It makes devices arrangement easily. The motor control singles are send and the value of absolute value encoder velocity encoder and current sensor is transmitted on the CAN bus. The control system is shown as Fig. 1.

The communication system is consisted of Ethernet fiber optic transmitter, fiber optic and switchboard. All single is transmitted by the Ethernet. Then it is changed to optic single by fiber optic transmitter and is changed to net single by fiber optic receiver. The fiber optic is winded around the wire coil and is realized when the fiber wire coil rotates. The communication system uses the hybrid of wireless and cable. The fiber cable is as the long distance communication media and its weight is lighter. And the bandwidth of the fiber cable is very huge. Each robot carries 1000 meters fiber cable. The cables connect through the wireless model. The communication system is shown as Fig. 2. The robot can communicate up to 3000 meters through this system.

The video single from three web cameras is transferred on the Ethernet and supplies the power on Ethernet technology (PoE). The PoE technology is used to transmission the single and power by a network cable.

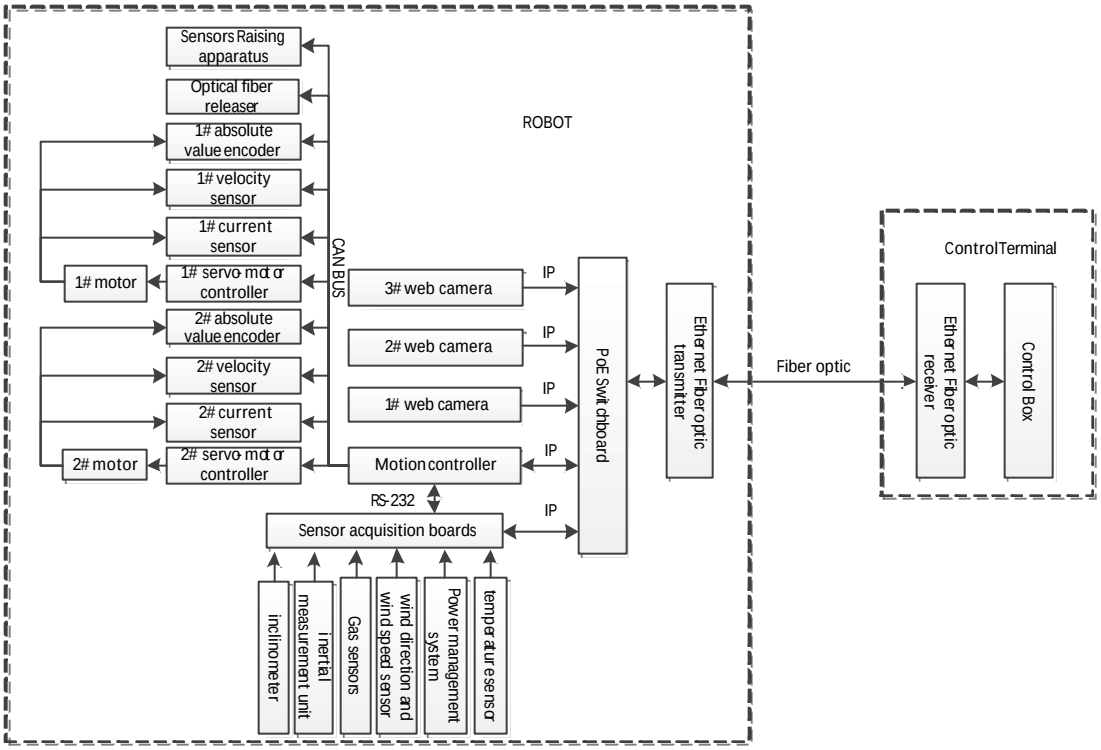

Fig. 1: Open control system based on ether net

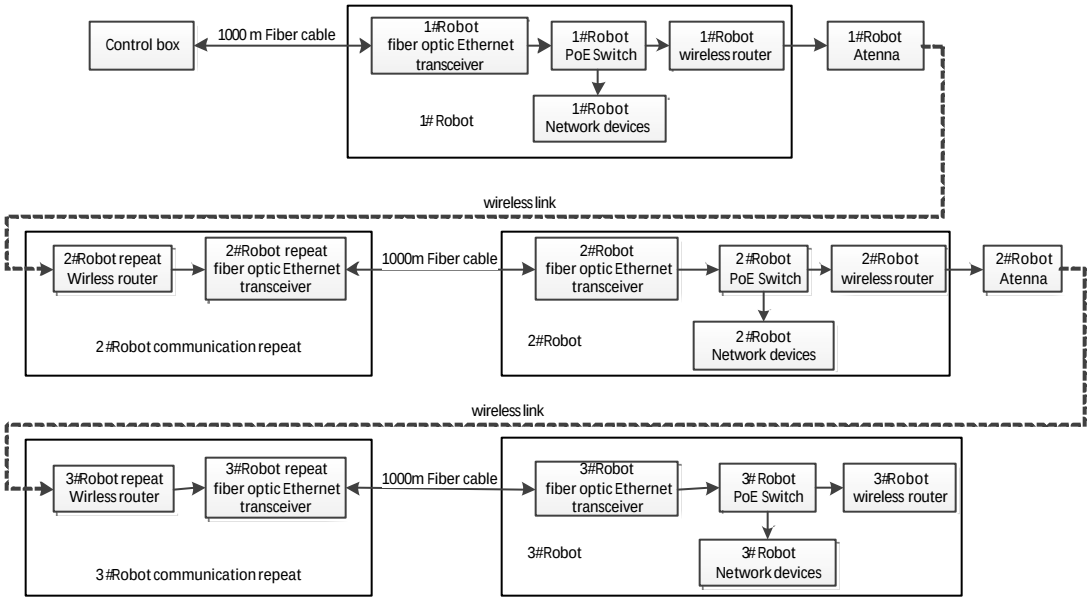

Fig. 2: Communication system

Figure 3 shows the robot and Fig. 4 shows the control box. The motor driver, controller, communication modeland batteries are laid in the explosion-proof box. And the explosion-proof box is as the robot body. Explosion-Proof Motor is fixed two sides of the body and connects with the driver wheel of the track. The gas

Fig. 3: Coal mine rescue robot

Fig. 4: Control box

sensors are laid on the cover of the explosion-proof box. The fiber wire coil is fixed on the back of the robot but is 1000 m long. The control box is consisted of IPC, battery and explosion-proof box.

The software is based on C/S architecture. Web cameras, motion controller and Sensor acquisition board are servers and the control box is the client. They communicate by ether net and use TCP/IP protocols.

After the outdoor test, the robot has moved 3 hours with this control system. The commands from the control box has been executed accurately and the video single and gas sensors data has been transmitted correctly. Especially, it can work reliably in the hard vibration and shock environment. Experiments show the performance of this system is according to design requirements and it has high reliability and anti-interference.

CONCLUSIONS

In this study, we analysis the requirements of the mine rescue robot which adapts to the mine disaster environment. And it is studied the advantages and defects of the existing mine rescue robot control system architecture in China is researched. After that, we proposed distributed control architecture based on Embedded System and CAN bus. The outdoor test shows this control system is effective and reliability. And its extensibility and open is excellent.

ACKNOWLEDGMNETS

The work is supported by the National High-Tech Research and Development Program of China (Grant No. 2012AA041504).

REFERENCES

Chai, H., 2007. Research and design on Crawler type mobile robot control system. Master's Thesis, Shandong University.

Fan, Y. and M. Tan, 1999. Current state and tendencies in the development of robot controller. Robot, 1: 76-81.

Gao, J.Y., X.S. Gao and J.G. Zhu, 2009. Coal mine detect and rescue robot technique research. Proceedings of the International Conference on Information and Automation, June 22-24, 2009, Zhuhai, Macau, pp: 1068-1073.

Hou, X.L., Z.B. Ge and X .D. Li, 2009. Design of under-mine rescue robot. Coal Mine Mach., 8: 18-20.

Li, K.J., 2003. Research on the development and strategy of robot risk. Robot Tech. Appl., 5: 14-22.

Murphy, R.R., J. Kravitz, S. Stover and R. Shoureshi, 2009. Mobile robots in mine rescue and recovery. Robotics Automation Magazine, IEEE, 16: 91-103.

Sun, J.P., 2010. Technologies of monitoring and communication in the coal mine. J. China Coal Soc., 11: 1925-1929.

Wang, T.R. and D.K. Qu, 2002. Open system architecture for control system for industrial robot. Robot, 3: 256-261.

Wang, Z., 2007. Design a control system of a mine robot and analyze its motion performance. Master's Thesis, Harbin Institute of Technology.

Zhao, J., G.F. Liu and L. Zhu, 2009. Multi-robot system for search and exploration in the underground mine disasters based on WSN. J. China Coal Soc., 7: 997-1002.

Zheng, Z.Z., S.R. Ge and Y.Y. Hou, 2009. Control system of coal mine rescue robot based on PC104. Coal Mine Mach., 4: 119-122.

Zhou, W. and Y.Z. Li, 2009. Design of the coalmine rescuing and detecting robot and its control system. Mining. Process. Equip., 19: 7-10.

Zhou, X.C., W.P. Li and Q. Li, 1998. Study of open type robot control system based on network. Robot, 1: 26-32.