

Analysis of multi-sensor information fusion and knowledge discovery in coal mine gas monitoring

Biqing Li¹, Suping Jiang^{2,*}, Hongyan Zhang¹

¹ School of Information and Communication Engineering, Hezhou University, Hezhou Guangxi 542899, China;

² Guangxi Talent International College, Qinzhou Guangxi 535000, China.

*Corresponding author e-mail: 229292710@qq.com

Abstract. This paper firstly analyses the defects of coal mine gas safety monitoring system from the aspects of sensor performance, management monitoring and monitoring technology, and puts forward some improvement opinions from aspects of comprehensive analysis capability to be strengthened, early warning function improvement and so on, and analyses the features of the system structure of multi - sensor information fusion.

Keywords: Coal mine; gas monitoring; multi-sensor.

1. Introduction

At present, the safety monitoring system of coal mine gas has the following shortcomings:

(1) The performance of the sensor is poor. The gas sensor is the essential technical equipment of mine gas comprehensive treatment, and it is also the primary component of the coal mine safety monitoring system. Its reliability and stability directly affect the accurate perception underground environment of coal mines. However, almost all sensors use carrier catalytic elements to sense concentration in domestic. Compared with similar products abroad, there is still a significant gap in the stability, reliability, adjustment period and service life for safety monitoring sensors in domestic. Notably, the sensitive components have the disadvantages of poor in resistance to high concentration impact, low sensitivity, zero drift and so on. As a result, it has severely restricted the upgrading the gas safety monitoring capability of mines in China.

(2) for workers at all levels in the safety monitoring center to perceive the working environment of underground coal mines. However, gas sensor components often fail to be repaired in time and become "sick" in the real production process. What is more, the number of sensors is not enough, and some sensors cannot adjust themselves according to the regulations. Moreover, the position of some sensors suspension is improper, and even some people intentionally block the sensor probe for various purposes. The above reasons often cause the gas sensing data incorrect, and the safety monitoring alarm misreports or fails to report. In others words, the safety monitoring system does not work accurately. Therefore, some hazardous situations cannot be handled correctly in time and may cause some massive gas accidents.

(3) The methods of on-line monitoring are limited. At present, there are two categories related to gas safety monitoring in coal mines, which are dynamic monitoring and static monitoring. The primary



dynamic monitoring methods are based on the series of "management specification for coal mine safety monitoring system and testing instrument" which issued by the State Administration of Work Safety. Moreover, it monitors the change of gas concentration by gas sensors which set in the monitoring points in roadways. At first, safety monitoring technicians set the acousto-optic alarm value of gas concentration. Once the gas concentration exceeds the limit, the alarm will be sounded. Then, workers have to deal the situation by following some relevant regulations. However, due to various factors such as reliability, such a single monitoring method is always an essential matter for the safety monitoring alarm misreports or fails to report.

(4) The comprehensive analysis ability needs to be improved. Safety monitoring often requires the monitoring center staff to provide accurate monitoring system fault locations in the real working environment. Is the fault location coming from the sensor, monitoring substation or communication cable? Is the reason for gas alarming comes from short circuit, ventilation system or other aspects? In this way, it can help to facilitate ventilation scheduling and let the gas detection technician take prompt measures to deal with in time.

(5) Early warning function is apparently insufficient. Use gas concentration sensors to monitor the gas concentration in the working face and roadway wall. Of course, it can reduce the possibility of gas accidents in a specific range. However, this monitoring method is apparently lack of early warning ability for coal mine working face and gas dynamic disaster. What is more, the time for preventing and treating coal and gas outburst disasters is too short. And the time for underground miners to escape the catastrophe is also too short. Therefore, there is a significant gap between the ideal situation and the current state regarding safety monitoring. The function of the gas safety monitoring system cannot entirely play.

(6) A solution needs to figure out to solve these shortcomings of the gas safety monitoring system. The solution should base on the risk prediction technology and the early warning theory regarding coal and gas outburst and gas explosion. What is more, the solution also needs to integrate all existing gas safety monitoring methods efficiently. Moreover, it needs to fully tap all kinds of sensor data, such as gas, acoustic emission, electromagnetic radiation, temperature, wind speed, along with their fundamental knowledge. In this way, it can entirely play to the advantages of all kinds of sensors.

2. Information fusion and knowledge discovery of multiple sensors regarding coal mine gas monitoring.

(1) Information fusion and knowledge discovery are technologies for data processing and extracting useful knowledge. Information fusion is an information processing method for the use of multiple and multi-class sensor systems. Knowledge discovery is to discover the relationship between patterns and knowledge and internal connection in data. Moreover, knowledge discovery is a combination of artificial intelligence, statistical theory, and database subject. Although these two technologies are different in principle, target, and processing, they complement each other in function. What is more, they can carry on deep combination and penetration; it can complete the analysis of complex data efficiently and solve the problems in practical application.

(2) In recent years, technicians have paid considerable attention to the research and application of using information fusion technology regarding multi-sensors to solve practical problems both in the military and non-military fields. What is more, they are using this technology to improve military or economic benefits, monitor the environment, recognize targets, position and track military targets like aircraft, ships, missiles and so on. As the industrial system becomes more and more complicated and intelligent, this technology has been popularized in the civil field in recent years, such as medical diagnosis, intelligent transportation, robot and intelligent manufacturing.

3. The system structure of multi-sensor information fusion

The excellent structure will significantly enhance the overall efficiency of the system. Therefore, all elements of the system should set according to the principles of scientific, reasonable and efficient. At

present, the academic world accepts that the multi-sensor information fusion structure has three levels, namely data level, feature level and decision level.

(1) Data level fusion. Its chief task is to merge and sort out the observed data of the same physical phenomenon observed by all homogeneous sensors. Therefore, the next step is to extract feature vectors from the fused data and identify them. Because the amount of data is enormous, this level of integration requires higher system communication bandwidth. As a result, the outcome of this integration is also the most accurate, and there is no data loss problem.

(2) Feature level fusion. The chief task is to extract the observed data from each sensor. After that, it incorporates the representative features into a feature vector. Then, according to the specific objectives of the problem, using scientific and rational pattern recognition methods to make preliminary judgments respectively. Because feature extraction often analyzes the data as a whole, it ignores some details, so that its accuracy decreases.

(3) Decision level fusion. The chief task is to fuse the initial recognition results of each sensor. Because it has the minimum amount of data transmission in these three levels, the requirement of communication bandwidth is also the lowest.

In addition to the above three levels of fusion structure, in view of the specificity of different application fields, there are several other classification methods regarding fusion structure. For example, according to the type of input and output data, there are several fusions such as data in data out fusion, feature in feature out fusion, decision in decision out fusion, data in feature out fusion, feature in decision out fusion and data in decision out fusion.

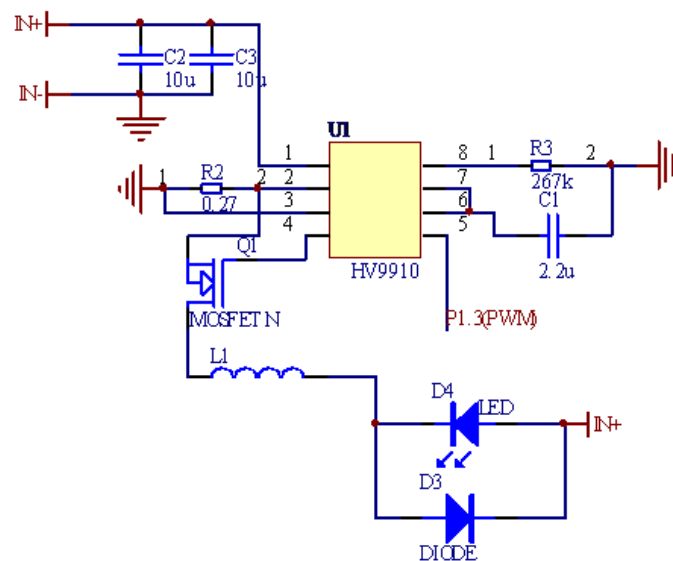


Figure 1. The system structure circuit

4. Multi-sensor information fusion method

There are a wide variety of information fusion methods, among which the classical methods have estimation methods (including weighted averages method, maximum likelihood estimation method, least square method, Kalman filter) and statistical methods (including evidence theory, estimation, quality factor method, etc.). On the other hand, modern methods include information theory methods (including cluster analysis, template method, entropy theory) and artificial intelligence methods (including fuzzy logic, expert system, neural network, genetic algorithm, etc.).

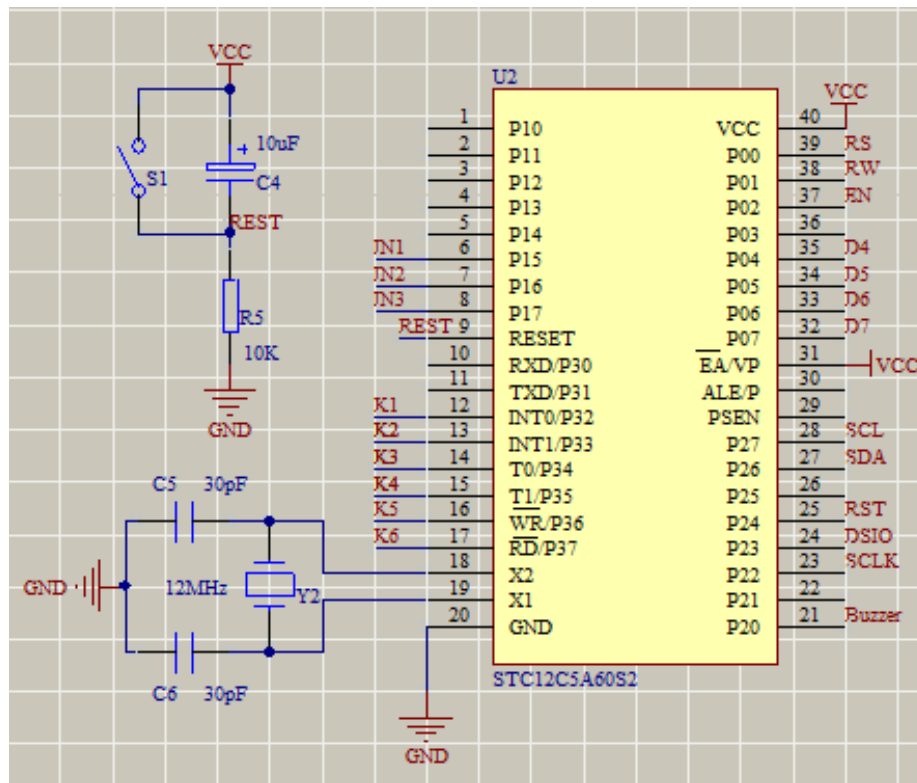


Figure 2. Multi-sensor controller

5. Multi-sensor information fusion for gas monitoring

In recent years, the theory and method of multi-sensor information fusion have made positive progress. These developments reflected in the collection and processing of all kinds of gas sensing data from coal mines. Many scholars focus on the research topic of improving the safety monitoring and early warning ability of coal mine gas. What is more, it further promotes the scientific development of multi-sensor information fusion. By combining all kinds of documents, there are many differences in the research of gas monitoring information fusion. These differences are mainly focused on the structure, criteria, and methods of integration. There are seldom feedbacks from using decision fusion output information apply to the environment through security scheduling management measures.

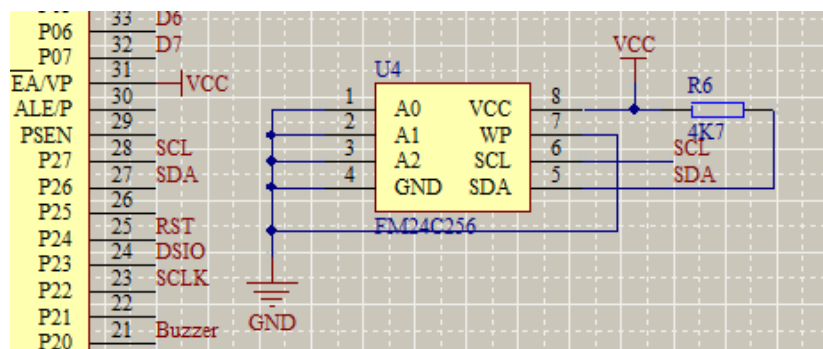


Figure 3. gas monitoring controller

6. Knowledge discovery of gas monitoring

The lack of expert knowledge of gas monitoring is the bottleneck of the effectiveness of multi-sensor gas monitoring system. Knowledge discovery has become an interdisciplinary subject. What is more,

knowledge discovery is a technology to discover potential knowledge from large amounts of data. Moreover, it is one of the hotspots in computer science research. Finding rules is the only way for human beings to understand nature and change nature. It is also the most effective way for different industries to pursue their ability and efficiency. Researchers in different fields start from their actual requirements and use information technology to study knowledge discovery from the extensive data accumulated in their industries. Therefore, there are also many new terms similar to knowledge discovery. For instance, data mining, information discovery, knowledge extraction, intelligent data analysis, data archaeology and so on. Among them, the most common terms are knowledge discovery and data mining.

7. Conclusion

Through months of continuous learning and practice, the research was finally completed. Among them, a lot of problems area encountered, such as the failure of motor rotation, which was, as later found out in repeated inspection, due to the short circuit caused by false welding in the original welding.

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References

- [1] B.Q LI, Y.F LING, M TIAN, S.Y ZHENG: Design and implementation of sugarcane growth monitoring system based on RFID and ZigBee. International Journal of Online Engineering, 3(14), 96-106, (2018).
- [2] B.Q LI, M TIAN, S.Y ZHENG, Y.F LING : Design and research of picking manipulator obstacle avoidance system based on IOT. International Journal of Online Engineering, 3(14), 96-106, (2018).
- [3] B.Q LI, Y.F LING, H.Y ZHANG, S.Y ZHENG: The Design and Realization of Cherry Tomato Harvesting Robot Based on IOT. International Journal of Online Engineering, 12(12), 23-25, (2016).
- [4] B.Q LI, W.L GUAN, S.Y ZHENG, X.G Yue: OPTIMISATION DESIGN OF CORN PRECISION SEEDER BASED ON MULTI-ROUTE AND MULTI-CHANNEL CONTROL. JOURNAL OF THE BALKAN TRIBOLOGICAL ASSOCIATION, 21(4A), 1215, (2015).
- [5] B.Q LI, X.M YANG GUAN, S.Y ZHENG: Internet of Things-based Simulation Study on Lijiang River Water Environment Monitoring. Journal of Coastal Research, 79, 1-5, (2017).
- [6] B.Q Li, et al, Design of a Tea Garden Antifreezing Control System, in: PROCEEDINGS OF THE 2016 6TH INTERNATIONAL CONFERENCE ON MACHINERY, MATERIALS, ENVIRONMENT, BIOTECHNOLOGY AND COMPUTER (MMEBC), Tianjin, China, 2016, PP.736-738.

- [7] B.Q Li, et al, Design of Electronic Compass, in: PROCEEDINGS OF THE 2016 6TH INTERNATIONAL CONFERENCE ON MACHINERY, MATERIALS, ENVIRONMENT, BIOTECHNOLOGY AND COMPUTER (MMEBC), Tianjin, China, 2016, PP.1240-1243.
- [8] B.Q Li, et al, Research of Automatically Light-Adjusting Lamp, in: PROCEEDINGS OF THE 2016 INTERNATIONAL CONFERENCE ON COMPUTER ENGINEERING, INFORMATION SCIENCE & APPLICATION TECHNOLOGY (ICCIA 2016), Guilin, China, 2016, PP.249-252.
- [9] B.Q Li, et al, The Design and Realization of Fruit Harvesting Robot Based on IOT, in: PROCEEDINGS OF THE 2016 INTERNATIONAL CONFERENCE ON COMPUTER ENGINEERING, INFORMATION SCIENCE & APPLICATION TECHNOLOGY (ICCIA 2016), Guilin, China, 2016, PP.261-264.
- [10] B.Q Li, et al, A New Type of Automatic Opening and Closing Light-Operated Curtain, in: PROCEEDINGS OF THE 2016 INTERNATIONAL CONFERENCE ON MECHATRONICS ENGINEERING AND INFORMATION TECHNOLOGY (ICMEIT), Xian, China, 2016, PP.66-69.
- [11] B.Q Li, et al, Design of the Intelligent Air Humidifier, in: PROCEEDINGS OF THE 2016 INTERNATIONAL CONFERENCE ON MECHATRONICS ENGINEERING AND INFORMATION TECHNOLOGY (ICMEIT), Xian, China, 2016, PP.201-203.
- [12] B.Q Li, et al, The Design Implementation of the APP of Experiencing Guangxi Folk Custom, in: PROCEEDINGS OF THE 2016 INTERNATIONAL CONFERENCE ON ECONOMICS AND MANAGEMENT INNOVATIONS, Wuhan, China, 2016, PP.47-50.
- [13] S.Y Zheng, et al, Digital Display Design of Ethnic Clothing of Nanling, in: PROCEEDINGS OF THE 4TH INTERNATIONAL CONFERENCE ON MECHATRONICS, MATERIALS, CHEMISTRY AND COMPUTER ENGINEERING 2015 (ICMMCCE 2015), Xian, China, 2015, PP.2805-2808.
- [14] S.Y Zheng, et al, Design and Implementation of Supermarket Personnel Management System Based On Java, in: PROCEEDINGS OF THE 2015 INTERNATIONAL CONFERENCE ON EDUCATION, MANAGEMENT AND COMPUTING TECHNOLOGY (ICEMCT-16), Hangzhou, China, 2016, PP.957-960.
- [15] S.Y Zheng, et al, Brief analysis on "HeYuanTong" Campus Mobile Phone APP Design, in: PROCEEDINGS OF THE 2015 5TH INTERNATIONAL CONFERENCE ON COMPUTER SCIENCES AND AUTOMATION ENGINEERING, Sanya, China, 2015, PP.151-154.
- [16] S.Y Zheng, et al, Social Work in Teen Addiction Correction Services Research Under the New Situation, in: PROCEEDINGS OF THE 2015 4TH NATIONAL CONFERENCE ON ELECTRICAL, ELECTRONICS AND COMPUTER ENGINEERING (NCEECE 2015), Xian, China, 2015, PP.252-255.
- [17] B.Q Li, et al, The Design of Remote Temperature Monitoring System, in: International Conference on Green Energy and Sustainable Development, MAY 27-28, 2017, PP.20-22.
- [18] B.Q Li, et al, Design of Portable Valuables Touch Alarm Circuit, in: International Conference on Advances in Materials, Machinery, Electronics, 2017, PP.27-32.
- [19] B.Q Li, et al, Design and Implementation of a Simple Acousto Optic Dual Control Circuit, in: 5th International Conference on Computer-Aided Design, Manufacturing, Modeling and Simulation, 2017, PP.78-80.
- [20] B.Q Li, et al, Design of electronic lock based on single-chip microcomputer, in: 4th International Conference on Electrical and Electronics Engineering and Computer Science, 2017, PP.55-60.
- [21] B.Q Li, et al, The Design of Chicken House Electronic Intelligent Lighting Apparatus, in: International Conference on Mechanical, Electronic, Control and Automation Engineering, 2017, PP.15-20.
- [22] B.Q Li, et al, Office Automation Sub-Summary of the Work and the Project Management System, in: International Conference on Mechanical, Electronic, Control and Automation Engineering, 2017, PP.46-48.

- [23] B.Q Li, et al, The Design of Intelligent Heat Dissipator Control Circuit,in:PROCEEDINGS OF THE 2017 2ND INTERNATIONAL CONFERENCE ON MATERIALS SCIENCE, MACHINERY AND ENERGY ENGINEERING,2017, PP.22-25.
- [24] B.Q Li, et al, The Design of IPv6's Transitional Scheme in University,in:International Conference on Materials Science, Energy Technology, Power Engineering (MEP) ,2017, PP.91-93.
- [25] B.Q Li, et al, The Personal Receiving Document Management and the Realization of Email Function in OAS,in:International Conference on Materials Science, Energy Technology, Power Engineering (MEP) ,2017, PP.121-123.
- [26] S.Y Zheng, et al, Design and Implementation of an Audio Indicator,in: 5th International Conference on Computer-Aided Design, Manufacturing, Modeling and Simulation,2017, PP.21-23.
- [27] S.Y Zheng, et al, Implementation and Application of ACL in Campus Network,in: International Conference on Advances in Materials, Machinery, Electronics ,2017, PP.151-153.
- [28] S.Y Zheng, et al, The Design of Liquid Drip Speed Monitoring Device System Based on MCU,in:International Conference on Green Energy and Sustainable Development, MAY 27-28, 2017, PP.51-53.
- [29] S.Y Zheng, et al, The Design of Hearing and hypnosis all-in-one Machine,in:International Conference on Mechanical, Electronic, Control and Automation Engineering,2017, PP.66-68.
- [30] S.Y Zheng, et al, Campus Network Security Defense Strategy,in:International Conference on Mechanical, Electronic, Control and Automation Engineering,2017, PP.30-33.
- [31] S.Y Zheng, et al, Design and implementation of multifunctional charger,in:International Conference on Materials Science, Energy Technology, Power Engineering (MEP) ,2017, PP.71-73.
- [32] B.Q Li, et al, Intelligent Control Management System and Its Application, in: PROCEEDINGS OF THE 2016 INTERNATIONAL CONFERENCE ON ECONOMICS AND MANAGEMENT INNOVATIONS, Wuhan, China, 2016, PP.68-71.
- [33] B.Q Li, et al, Design and Implementation of Tanks War Game Based on the Android Platform, in: PROCEEDINGS OF THE 2016 2ND WROKSHOP ON ADVANCED RESEARCH AND TECHNOLOGY IN INDUSTRY APPLICATIONS, Dalian, China, 2016, PP.963-966.