Available online at www.ijpe-online.com

International Journal of Performability Engineering

vol. 15, no. 12, December 2019, pp. 3279-3286
DOI: 10.23940/ijpe.19.12.p20.32793286

Control Method of Multi-Split Wireless Remote Monitoring System

Zhihui Zhuang[a], Jian Cen[a], and Shuai Liu[b,*]

[a]*School of Automatization, Guangdong Polytechnic Normal University, Guangzhou, 510000, China*
[b]*State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System, Luoyang, 471000, China*

Abstract

In order to maintain the normal operation of production equipment, achieve the maximum utilization of personnel and the purpose of reducing personnel without reducing efficiency. It is necessary to research the control method of multi-split wireless remote monitoring system. At present, the method of controlling the multi-split wireless remote monitoring system based on fuzzy PID controller is commonly adopted. Firstly, the data of the multi-split wireless remote monitoring system was collected. Secondly, the wavelet transform was used to smooth the data and remove the interference data. Finally, fuzzy PID controller was used to control the multi-split wireless remote monitoring system online. Due to the fuzzy PID controller, although the current method can achieve comprehensive control, large control error and serious network congestion are the main problems. In order to accurately analyze the current network situation and reduce the network delay rate, a method to control the multi-split wireless remote monitoring system based on neuron PID controller was put forward. Firstly, the relevant data of multi-split wireless remote monitoring system were collected. Then, the network prediction function was used to analyze current network situation of the remote monitoring system, and the relevant network data parameters were calculated. According to the calculation results, the neural PID controller was used to achieve the real-time control for the multi-split wireless remote monitoring system. Simulation results show that the proposed method can predict and analyze the current network conditions accurately and avoid network congestion. Thus, real-time control for the remote monitoring system is achieved.

Keywords: wireless remote monitoring system; control method; network prediction function; neuron PID controller

(Submitted on November 4, 2019; Revised on December 6, 2019; Accepted on December 20, 2019)

1. Introduction

With the continuous progress of science and technology, great changes have taken place in production and life. As a basic technology, the remote monitoring technology is gradually recognized and valued by people [1]. With the continuous development of remote monitoring system, the monitoring equipment is becoming more and more and the technical requirement is also rising [2]. The remote monitoring technology mainly has the following functions, The first is the collection and processing function for network data; the second is the monitoring function of network data; the third is the alarm management of network emergencies; the fourth is the control function for network data processing on the basis of detection [3-4]. With the help of the remote monitoring system, the information network control network of government agencies or enterprises can be effectively connected, so as to control the industrial production and operation status at any time [5]. Meanwhile, this system can connect the production and operation with the operation and management policies of enterprises closely, which achieves the automatic management of enterprises. In addition, the database of remote monitoring data and network resources in the effective network area be built. Then the timely collection and centralized processing for operation data of production site can be achieved by the remote monitoring system, so that more accurate production data information can be obtained, which provides the data support for remote fault diagnosis technology [6]. The control for the remote monitoring system can realize the maximum utilization of the personnel, so as to achieve the purpose of reducing the number of staff without reducing efficiency. Traditionally, the control method of multi-split wireless remote monitoring system based on PID control firstly extracts the network data, and then analyzes the characteristics of network data of the remote control system. Finally, PID control method is used to achieve the real-time control for the multi-split wireless remote monitoring

* Corresponding author.
E-mail address: cs.liu.shuai@gmail.com

system. However, traditional method is difficult to obtain accurate network data features in time, which limits its applicability. In order to improve the stability of system, accelerate the response speed, improve the adjustment speed and the real-time monitoring performance, many researchers have focused on it. Because the control of multi-split wireless remote monitoring system can provide more convenient services for production and life, it has important practical value. Therefore, this article puts forward a series of effective methods.

In Reference [8], a control method of multi-split wireless remote monitoring system based on fuzzy PID controller is presented. Firstly, the data of multi-split wireless remote monitoring system is collected. Then, the data is smoothed and denoised by wavelet transform, and the interference data is filtered out. Finally, the fuzzy PID controller is used to control multi-split wireless remote monitoring system on line. Because of using fuzzy PID controller, this method can realize a more comprehensive system control, but it has the problems of large control error and serious network congestion. In Reference [9], a control method of multi-split wireless remote monitoring system based on professional PID controller is proposed. Firstly, the network data of multi-split wireless remote monitoring system wireless remote monitoring system is extracted. Secondly, the extracted network data features are classified by support vector machine. Finally, the control of multi-split wireless remote monitoring system is achieved by professional PID controller. In the process of feature data extraction, the calculation process of the method is complex and there are a lot of interference data in features. In Reference [10], a control method based on adaptive multi-split wireless remote monitoring system is proposed. Firstly, the data of multi-split wireless remote monitoring system is extracted. Secondly, the extracted data features are smoothed and denoised by high-pass filter. According to the processing results, the adaptive algorithm is used to control the multi-split wireless remote monitoring system in real time. This method has the problems of poor control stability and low control accuracy.

In this article, the problems of above methods in the process of controlling multi-split wireless remote monitoring system are improved. Therefore, a method of controlling the multi-split wireless remote monitoring system based on neuron PID controller is proposed. Experimental results show that the application of network prediction function improves the current network congestion and avoids the sudden suspension of remote monitoring system communication caused by busy network. Thus, the proposed method can achieve the real-time control for the remote monitoring system with low cost.

2. Research on Method to Control Multi-Split Wireless Remote Monitoring System

2.1. System Frame Design

The overall architecture of the system is shown in the Figure 1.

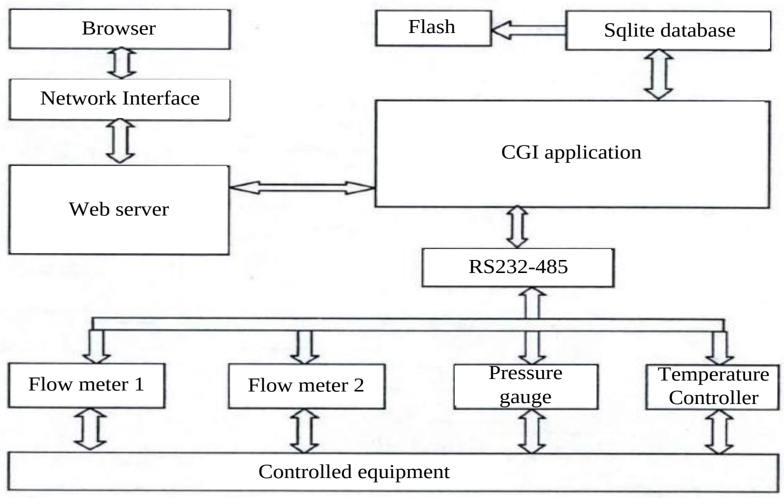

Figure 1. Embedded system block diagram

As seen from Figure 1, the CGI code is the interface of the system. It is set by CGI specific standards, without having to rewrite the code, only modifying the source code in the system slightly. It is itself an interface with specific functions. Data can be collected and parsed according to the needs of the system to complete the corresponding operations. The interface module can receive and feedback user information. The data storage module is composed of

Flash and SQlite database. After the embedded system collects the data, the database of the calling system has the function of saving and viewing. The use of the database can support the operation of the other three modules, providing a software foundation for the operation of the system.

2.2. Network Condition Analysis and Parameter Calculation of Multi-Split Wireless Remote Monitoring System

Firstly, the relevant data is collected during the real-time transmission, so that the relevant network data parameters are calculated and analyzed. Then, current network status of the multi-split wireless remote monitoring system is analyzed by the network prediction function [11-12]. The specific process is as follows.

J denotes the delay jitter of data packets arriving at the receiving end; the increase of J represents the network congestion of remote monitoring system. S denotes the time stamp of data packaging in the sending end remote monitoring system; R denotes the arrival time of receiving the transmission protocol packets at the receiving end of remote monitoring system. i and j denote the data packets of remote monitoring system. Thus, the formula of calculating relative transmission delay difference of the two data packets is as follows:

$$D(i, j) = (R_j - R_i) - (S_j - S_i) = (R_j - S_j) - (R_i - S_i) \tag{1}$$

The delay J of the data packet in remote monitoring system arriving at the receiving end is obtained by continuous calculation. After receiving the source data packet i from the remote monitoring system every time, the delay difference between the data packet $i-1$ of the remote monitoring system with the nearest arrival distance and the source data packet i is calculated. The formula is as follows:

$$J(i) = J(i-1) + (|D(i-1, i)| - J(i-1)) / \omega \tag{2}$$

Where ω denotes the attenuation coefficient of data packet in the multi-split wireless remote monitoring system.

The sending terminal of data package in remote monitoring system is s. The conversational receiving terminal of remote monitoring system is r. p denotes the network packet received by the conversational terminal of remote monitoring system from the sending terminal s of data package in remote monitoring system. T_{rep} denotes the feedback time when r receives the data package in remote monitoring system network and r sends the feedback information to the sending terminal s of data package in remote monitoring system（This period of time is mainly used to process and analyze the data transmission protocol message of multi-split wireless remote monitoring system）. r can extract the time stamp of data transmission protocol from p, so as to obtain the p sent by the nearest remote monitoring system data packet sending end s, which is expressed as the time stamp T_{se}.

If the time receiving packet of the remote monitoring system through r is T, the formula to calculate the network packet transmission delay time T_D of remote monitoring system is as follows:

$$T_D = T - T_{se} = T_{rep} \tag{3}$$

According to Formula (3), we can predict the network congestion and network information transmission of remote monitoring system to estimate the network transmission distance of remote monitoring system.

γ denotes the packet loss rate of remote monitoring system, and R_{ex} represents the expected data packet of remote monitoring system. If the minimum serial number of transmission protocol packet of remote monitoring system received by the receiving program of remote monitoring system before the time t is expressed as $S_{\min}$, and the maximum serial number of transmission protocol packet of remote monitoring system is expressed as $S_{\max}$, the expression of the expected number R_{ex} of network packets of remote monitoring system is:

$$R_{ex} = S_{\max} - S_{\min} \tag{4}$$

Supposing that the total number of network packets in the transmission protocol of remote monitoring system received at a certain time t is expressed as R_{re}, the formula of calculating the accumulative total R_{lost} of network packets of the remote monitoring system lost within time t is as follows:

$$R_{lost} = R_{ex} - R_{re} \tag{5}$$

According to Formula (4) and Formula (5), the packet loss rate of the remote monitoring system can be calculated:

$$\gamma = R_{lost} / R_{ex} \tag{6}$$

It is assumed that the packet loss rate of network data satisfies the function $f(x)$, including n network data discontinuous points $f(g_1), f(g_2), f(g_3), \cdots, f(g_n)$ which belong to the first species. Then, a network packet prediction function $P(x)$ of remote monitoring system is constructed [13-14]. Its expression is:

$$P(x) = f(x_i) + \frac{f(x_i) - f(x_i - 1)}{x_i - x_i - 1}(x_i + x_i - 1) \tag{7}$$

x_i denotes the sampling time of network packet in remote monitoring system. Thus, the formula to calculate the network data error of remote monitoring system is:

$$\mu = f(x_i + 1) - P(x_i + 1) = f(x_i + 1) - f(x_i) - \frac{f(x_i) - f(x_i - 1)}{x_i - x_i - 1}(x_{i+1} - x_i) \tag{8}$$

If $f(g_n)$ does not exist between x_{i+1} and x_i, Formula (8) can be further calculated as:

$$\mu \approx \frac{f^2(\xi)}{2}(x_{i+1} - x_i)^2 \tag{9}$$

ξ denotes the value of network data in the remote monitoring system between x_{i+1} and x_i. Therefore, the network data error μ of the remote monitoring system is very small.

Supposing that the network data prediction function of system is not adopted, we only use the last feedback of the remote monitoring system data as the next prediction. Thus, the network data error μ of the remote monitoring system is:

$$\mu = f(x_i + 1) - f(x_i) = f'(\varphi)(x_{i+1} - x_i) \tag{10}$$

φ denotes the value of network data in remote monitoring system between x_{i+1} and x_i. According to Formulas (9) and Formula (10), the network data error of the former is smaller than that of the latter. So, it is able to reflect the current network condition of the multi-split wireless remote monitoring system.

According to Formula (10), in the packet reception of the multi-split wireless remote monitoring network, R_{re} may contain the network data groups of late arrival and repeat arrival in the remote monitoring system, so the cumulative number R_{lost} of lost remote monitoring system network packets in time t may be negative. Thus, the network data packet loss rate of the remote monitoring system is set as zero.

2.3. Control Method of Remote Monitoring System based on Neuron PID Controller

Neuron PID controller is a new control method which applies neural network to PID control and combines with PID controller [15-16]. According to the condition analysis of multi-split wireless remote monitoring network and the calculation results of relevant parameters in Section 2.1, the control of remote monitoring system is achieved.

The calculation formula of PID controller is as follows:

$$u(t) = K_P \left[e(t) + \frac{1}{T_i} \int_0^t e(t)\mathrm{d}t + T_d \frac{\mathrm{d}e(t)}{\mathrm{d}t} \right] \tag{11}$$

Where, $e(t)$ denotes the error signal of multi-split wireless remote monitoring system; $\mathrm{d}e(t)/\mathrm{d}t$ denotes the error change of network data packet in remote monitoring system; T_i represents the integration time constant of network packet in the remote monitoring system; T_d represents the differential time constant of network packet in remote monitoring system; K_P denotes the proportion coefficient of data packet in remote monitoring system.

According to Formula (11), the corresponding discrete formula of multi-split wireless remote monitoring system can be calculated as follows:

$$u(k) = K_P e(k) + K_I \sum_{j=1}^{k} e(j) + K_D \left[e(k) - e(k-1) \right] \tag{12}$$

k denotes the serial number of network packet sampling of multi-split remote monitoring system. K_I represents the integration of data packet in the remote monitoring system [17-18]. K_D represents the differential coefficient of data packet in the remote monitoring system. $e(k)$ denotes the data input deviation value of the k^{th} sampling of the remote monitoring system. $u(k)$ represents the network data output value of k^{th} sampling of the remote monitoring system. $e(k-1)$ denotes the network data input deviation value of $(k-1)^{\text{th}}$ sampling of the remote monitoring system.

Then, the expression of incremental PID control algorithm of multi-split wireless remote monitoring system is as follows:

$$\Delta u(k) = K_P \Delta e(k) + \Delta K_I \Delta e(k) + K_D \Delta \left[e(k) - \Delta e(k-1) \right] \tag{13}$$

According to Formula (12), a single neuron PID controller is constructed; its formula is as follows:

$$X_2(k) = e(k) \tag{14}$$

Thus, the network data input expression of remote monitoring system is:

$$X_2(k) = \sum_{j=1}^{k} e(j) \tag{15}$$

$$X_3(k) = \Delta e(k) = e(k) - e(k-1) \tag{16}$$

According to Formula (13), the expression of network output of remote monitoring system is:

$$u(k) = W_1 X_1(k) + W_2 X_2(k) + W_3 X_3(k) \tag{17}$$

Where, W_i denotes the weighting coefficient of remote control system controller, which is equivalent to the proportional coefficient K_p, integral coefficient K_I and differential coefficient K_D in PID controller of remote control system [19-20]. Moreover, the weighting coefficient W_i of the remote control system controller can modify the network package of remote control system on line. By continuously adjusting the weighting coefficient W_i of the remote control system controller, it can achieve the optimal value W_*, and then the performance of the multi-split wireless remote monitoring system can be controlled.

3. Simulation Experiment Results and Analysis

In order to analyze the performance of the multi-split wireless remote monitoring controller, the neuron PID controller was installed on the remote monitoring system of desktop, the remote monitoring system of server and the remote monitoring system of laptop computer. The configuration of desktop: Intel Pentium Dual-CoreE6500 6.4GHz, 8GB memory, Windows 7 operating system. The configuration of server: Intel Corei7 820 3.20GHz, 4GB memory, Windows 2013 R6 Standard. The configuration of laptop computer: HP Elite Book828 G3 i7-6500U 8GB Windows8 operating system. The experiment selected one thousand pieces of network data at the receiving end and the sending end of the remote monitoring system, and controlled the data transmission and data reception of the whole remote monitoring system based on the neuron PID controller, including one monitoring node and six ordinary network nodes. The experiment results were collected. The network data flow characteristics of remote monitoring system are shown in Table 1.

Table 1. Characteristics of Network data flow of remote monitoring system

Data number (PCS)	Data length (Byte)	Period of transmission (μs)	Maximum allowable delay (μs)
R_1	300	150	150
R_2	800	90	90
R_3	900	200	200
R_4	1200	450	450
R_5	1800	580	580
R_6	180	120	120

The delay rate of network data in the multi-split wireless remote monitoring system is taken as the evaluation standard to measure the real-time performance of network, the network data delay rate is defined as:

$$Network\ data\ delay\ time\ rate = \frac{Time\ transmission\ delay\ of\ network\ data}{Maximum\ allowable\ delay} \tag{18}$$

Run for 20000 μs , the data collected from the network monitoring nodes in the remote monitoring system are shown in Table 2.

Table 2. Statistical table of experimental data results

Experiment item	Experimental data
Experimental time	20000 μs
Minimum delay rate	15.219%
Maximum delay rate	75.821%
Network average delay rate	45.520%
The number of network data exceeding the maximum allowable delay time of the network	0

According to the experimental data in Table 2, the network delay time rates (%) of multi-split wireless remote monitoring system are compared and analyzed by the methods of Reference [8], Reference [9], Reference [10] and this article. The analysis results are shown in Figure 2.

Figure 2 and Table 2 show that the network data transmission delay time of multi-split wireless remote monitoring system in Reference [8], Reference [9] and Reference [10] exceeds the maximum allowable delay time of network. The maximum delay time rate of the network is 75.821%. The proposed method can control the data transmission of multi-split wireless remote monitoring system well, which meets the real-time requirements of all data flows in network. Thus, the proposed method has good performance.

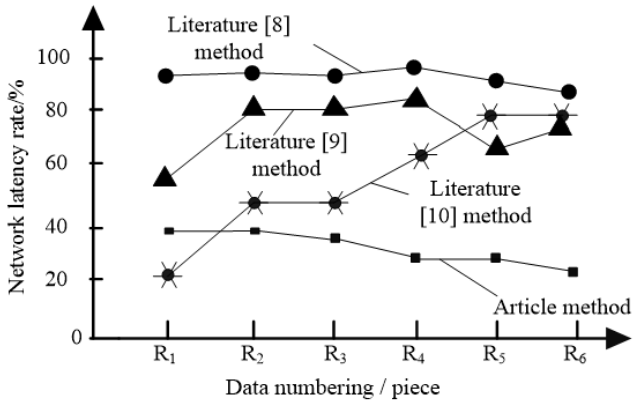

Figure 2. Comparison of network delay rates of different methods

In order to further verify that the method proposed can achieve real-time control for the multi-split wireless remote monitoring system, the influence of network packet prediction function $P(x)$ in Section 2.2 on the network response time (s) is cited in Figure 3.

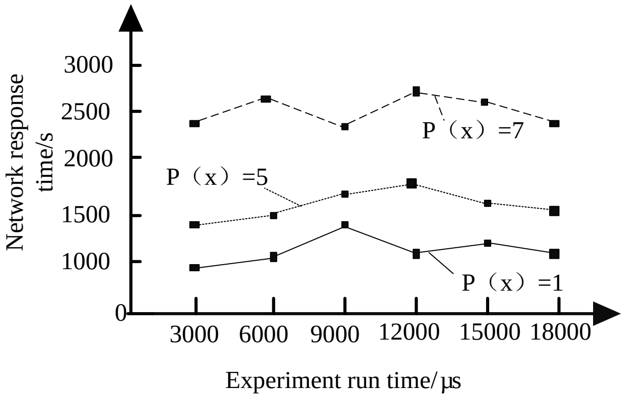

Figure 3. Influence of network packet prediction function on response time

The analysis results in Figure 3 shows that the network packet prediction function of the multi-split wireless remote monitoring system has an impact on the network response time. When $P(x) = 7$, the network response time slows down obviously, resulting in the network congestion. When the value of $P(x)$ is controlled within the range [1, 5], the network response time is the fastest. This means that the current network is not congested, so that the data transmission and reception of remote monitoring system can be controlled better. The validity of the proposed method is proved.

Simulation results show that the proposed method can realize the real-time control of the multi-split wireless remote monitoring system.

4. Conclusions

When using the current method to control the multi-split wireless remote monitoring system, we can't accurately predict and analyze the current network situation. It is prone to network congestion. The delay rate of network is too high. The transmission and reception of network data in remote monitoring system is not timely. Therefore, a method to control the multi-split wireless remote monitoring system based on Neuron PID controller is proposed. Simulation results show that the proposed method can analyze the current network conditions accurately, so that the network data transmission of multi-split wireless remote monitoring system can be achieved and the network delay rate can be reduced. Thus, the proposed method has good practical performance.

Acknowledgements

This work was supported in part by the National Natural Science Foundation of China under Grant 61502254, in part by the Program for Yong Talents of Science and Technology in Universities of Inner Mongolia Autonomous Region under Grant NJYT-18-B10, in part by the Open Project Program of the State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System under Grant 2019K0104B, in part by the Open Project Program of the State Key Lab of CAD&CG under Grant A1926, Zhejiang University.

References

1. Y. N. Wang, T. J. Chen, Z. D. He, et al., "Overview of Visual Inspection Control Methods for Intelligent Manufacturing Equipment," *Control Theory and Application*, Vol. 32, No. 3, pp. 273-286, March 2015
2. Y. H. Liu, C. Y. Guo, W. H. Xu, C. Y. Zhao, Y. X. Yang, and C. H. Li, "A Control Method to Reduce the Failure Probability of HVDC Commutation," *Grid Technology*, Vol. 39, No. 1, pp. 76-82, January 2015
3. Z. Q. Jian and S. T. Qin, "Control Method of Three-Phase Voltage Asymmetric Drop Photovoltaic Grid Connected Inverter," *Power System Protection and Control*, Vol. 43, No. 14, pp. 126-130, July 2015
4. F. Chang, X. F. Yang, H. L. Jia, et al., "MMC Capacitor Voltage Balance Control Method for Field Programmable Gate Array," *Grid Technology*, Vol. 39, No. 5,pp. 1246-1253, May 2015
5. H. F. Su and Z. R. Liang, "Orderly Charging Control Method for Residential Area of Household Electric Vehicle based on Peak Valley Price," *Electric Power Automation Equipment*, Vol. 35, No. 6, pp. 17-22, August 2015
6. X. Q. Huang, Y. Cao, W. L. Wu, C. Huang, and Y. J. Cao, "Study on Voltage Coordinated Control Method Considering Voltage Sag Index," *Power System Protection and Control*, Vol. 43, No. 22, pp. 147-154, November 2015
7. G. G. Yan, Y. Wang, J. H. Li, K. X. Feng, K. Gao, and P. Jin, "Control Method and Economic Evaluation of Energy Storage System Matching the Feasible Region of Wind Power Acceptance," *High Voltage Technology*, Vol. 41, No. 7, pp. 2148-2155, July 2015
8. X. P. Bai, J. T. Hu, L. Gao, et al., "Research on Self-Tuning Model Control Method of Agricultural Machinery Navigation," *Journal of Agricultural Machinery*, Vol. 46, No. 2, pp. 1-7, February 2015
9. W. Y. Zhang, Y. C. Ding, X. L. Wang, et al., "Tractor Navigation Pure Tracking Control Method based on SVR Reverse Model," *Journal of Agricultural Machinery*, Vol. 47, No. 1, pp. 29-36, January 2016
10. T. Hong, Y. F. Huang, and C. H. Chen, "Design of Flow Control Method for Vehicle Video Monitoring Terminal," *Electronic Design Engineering*, Vol. 24, No. 19, pp. 47-50, October 2016
11. L. Tao, Z. P. Wang, Bin S., et al., "Remote Monitoring System for Multi-Connected Air Conditioners," *Journal of Computer Systems*, Vol. 26, No. 2, pp. 88-92, March 2017
12. G. F. Li, "Research on Control Method of High Temperature Multi-Connected Air Conditioning System," *Science and Technology Economics Guide*, Vol. 25, No. 18, pp. 44-45, July 2018
13. J. X. Xue and Q. Y.Wang, "Research on Automatic Control and Remote Monitoring System of Communication Equipment Room," *Information Systems Engineering*, Vol. 297, No. 9, pp. 142-144, November 2018
14. J. L. Xu, L. Wang, and H. Zhang, "Timeliness Analysis and Countermeasures of Remote Control of Equipment Monitoring System," *Journal of Aircraft Measurement and Control*, Vol. 168, No. 4, pp. 287-294, July 2017
15. Y. Deng, C. Q. Li, and X. H. Chen, "Design of Remote Wireless Monitoring System for Smart Home based on Internet of Things," *Journal of Computer Applications*, Vol. 37, No. 1, pp. 159-165, February 2017
16. G. Yang and S. Liu, "Distributed Cooperative Algorithm for k-M Set with Negative Integer k by Fractal Symmetrical Property," *International Journal of Distributed Sensor Networks*, Vol. 10, No. 5, 2014
17. Y. Lin, Y. Li, X. Yin, and Z. Dou, "Multisensor Fault Diagnosis Modeling based on the Evidence Theory," *IEEE Transactions on Reliability*, Vol. 67, No. 2, pp. 513-521, 2018
18. Y. Lin, C. Wang, J. X. Wang, and Z. Dou, "A Novel Dynamic Spectrum Access Framework based on Reinforcement Learning for Cognitive Radio Sensor Networks," *Sensors*, Vol. 16, No. 10, pp. 1675, 2016
19. S. Liu, "Introduction of Key Problems in Long-Distance Learning and Training," *Mobile Networks and Applications*, Vol. 24, No. 1, pp. 1-4, 2019
20. A. D. Dwivedi, P. Morawiecki, and G. Srivastava, "Differential Cryptanalysis of Round-Reduced Speck Suitable for Internet of Things Devices," *IEEE Access*, Vol. 7, pp. 16476-16486, 2019