International Journal of Smart Home
Vol. 10, No. 5 (2016), pp. 69-78
http://dx.doi.org/10.14257/ijsh.2016.10.5.08

Design and Implementation of Livestock House Environmental Perception System Based on Wireless Sensor Networks

Weizheng Shen, Guanting Liu, Zhongbin Su, Rongyu Su and Yu Zhang*

College of Electrical and Information, Northeast Agricultural University, Harbin 150030, China
E-mail: 379119127@qq.com

Abstract

In order to monitor the six factors which is the most crucial influence on livestock production in livestock house, this paper designs a set of livestock house(LH) environmental perception system based on wireless sensor networks. This system is composed by a number of data acquisition nodes(DAN) connected by using Wireless Sensor Networks. Inside of DAN is equipped with six type of sensor which in charge of collecting Real-time environmental data in LH, including carbon dioxide sensor, ammonia gas sensor, illumination sensor, relative humidity sensor and so on. The communication mode between upper-computer and central node is GPRS, to research on remotely control environmental parameters in LH in the future. The upper-computer could treat data which is uploaded by several central nodes through some way, for example, data analysis based on established protocol, threshold judgment, etc. Then, the real-time data is stored by database. The stability and veracity of the system was verified by field tests which set technical grade monitors as control groups. Comparing with industrial-grade high precision monitoring instruments, the error of collecting data and wireless communication network is within normal error range, By SPSS, the result shows that there is no significant difference of P-Value(P>0.05) in different groups at same time.

***Keywords**: Data acquisition; Environmental monitoring; Livestock house*

1. Introduction

China is a vast country abundant in livestock and poultry breeding, animal husbandry output value has accounted for 34% of the total output value of agriculture. Due to the increase of market demand, the backward small-scale breading way has gradually been replacing by large-scale and intensive breading method, and Intensification is becoming an important direction of livestock production [1-2]. Rely on the traditional manual methods cannot meet the needs of the development of animal husbandry [3], therefore, The significance of LH interior microclimate scientific monitoring has become increasingly prominent.

So far, many universities and research institutions have developed a variety of LH environment monitoring system. For instance, Cugnasca C.E, comes from Brazil, has developed a set of instrument which could monitor three environmental parameters for improving animal welfare [4]. Then, a project team of Cong xi, come from JinLin agriculture university, has realized a device. That could monitor six types of environmental parameters in LH and Rui Li researched on the field of modern farm and realized a device with four kinds of sensors, and so on [5-6] . Many research results, at present, are only in the theoretical stage and the experimental stage, few of them have tested for a long time, the accuracy and stability of data acquisition and system still can not be verified before having mass field testing in LH. According to above present situation, the monitor system of LH environmental data based on Wireless Sensor

ISSN: 1975-4094 IJSH
Copyright ⓒ 2016 SERSC

Networks is developed in the paper aiming at constantly monitoring six critical parameters including carbon dioxide, hydrothion gas, ammonia gas, temperature, relative humidity and illumination in high latitude area [7], a experimental model has been used for experiment and measurement. Communication network using complete wireless way, it completely get rid of the drawbacks of cable transmission. GPRS (Packet Radio Service General) technology is used to upload data, greatly improving the distance between the server and the livestock and poultry house, and lay a good hardware foundation for the remote control of environmental parameters.

2. System Composition and Design

2.1. Overall Design

The system is composed of three modules, such as perception module, data processing module and environment control module. Overall design as shown in Figure 1, Sensing module, includes light sensor, temperature and humidity sensor, carbon dioxide sensor and other environmental parameter sensors, can collect real-time environmental parameters, Data processing module functions for comparing environmental parameters with threshold and storing into database after data analysis based on established protocol, and then uploaded to the host computer by the center node. Environmental control module mainly includes the heaters and wet curtain cooling fan, adjusts the environmental parameters in LH.

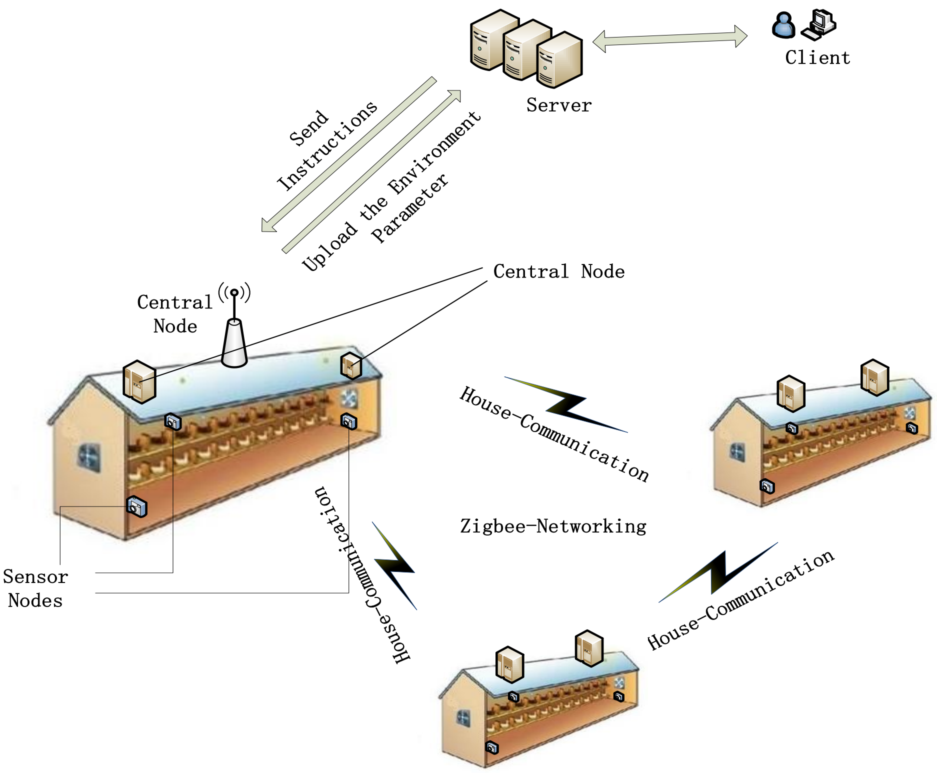


Figure 1. Overall System Design

2.2. System Hardware Design

The hardware part of the system is divided into terminal node and routing node according to the rules of ZigBee protocol. As shown in Figure 2, The terminal node collects the real-time environment parameters and collects them to routing nodes, and the

 Copyright ⓒ 2016 SERSC

routing nodes can also transmit the data to the upper computer by DTU [8-9]. Each node has a LCD display which could provide staff with real-time parameters.

Both of the two types of sensors are equipped with the MSP430F248 produced by TI (TI) which has some characters, for instance, lower cost and higher memory speed [10]. The data acquisition module is composed of carbon dioxide sensor (NDIR MH-Z14), hydrogen sulfide sensor (ME4-H2S), ammonia gas sensor (ME4-NH3), temperature and relatively humidity sensor (AM2302) and hydrogen sulfide sensor (ME4-H2S). Real-time environment parameters are displayed on the LCD display. The power supply mode of node is power adapter and battery power, ensuring its stability and durability.

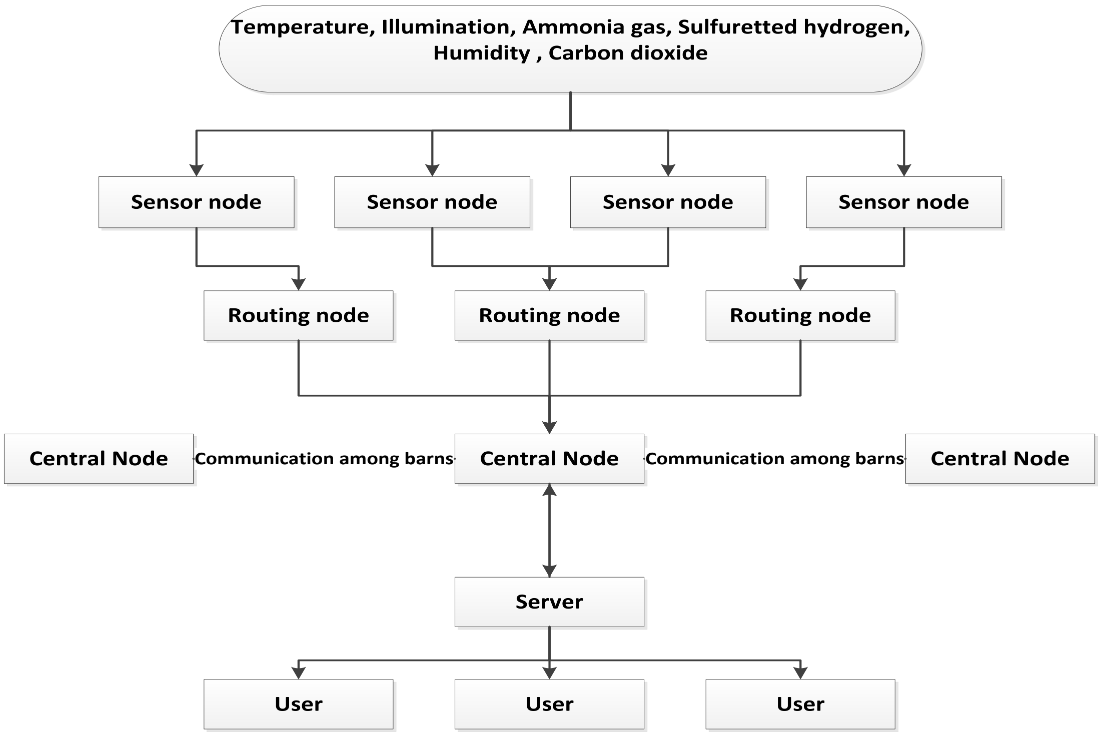


Figure 2. Hardware Structure Design

2.3. Software Overall Design

PC monitoring software(the upper computer) is divided into two parts, data receiving processing and remote control monitoring. Both of them are development in Visual C# language. many design patterns were used in the process of design, in order to improve the robustness of the software, such as Liskov Substitution Principle, abstract factory, the Law of Demeter and so on.

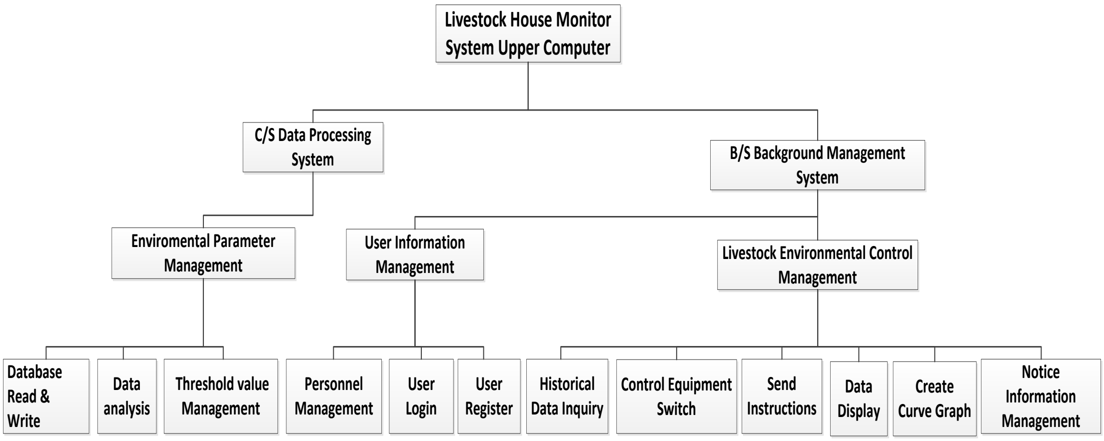


Figure 3. Upper Computer Functional Block Diagram

As shown in Figure 3, taking modular programming ideas, the upper computer data receiving analysis software is designed by C/S mode, divided into three modules, network communication module, data analysis module and data storage module. In the network communication module, the performance of sending instructions and receiving data with lower machine is by TCP protocol. Message header determination and data analysis is through the established message protocol in Data analysis module. In the data storage module, it uses ADO technology to add data, remove data, alter data, and query data and so on. Data flow diagram is shown in Figure 4. Remote monitoring interface is designed by B/S structure and ASP technology, integrating with data display, threshold alarm, message sending and receiving, database management, historical data query, data trends and many other functions. It also covers the traditional management system of personnel scheduling, authority setting and other management mode [11-12]. Therefore, it realized overall management and remotely control of personnel, LH and environmental parameters, and for every barn, it refers to the specific circumstances of the individual configuration to avoid many common problems in the actual production, thus improving production efficiency and ensuring the stability of production.

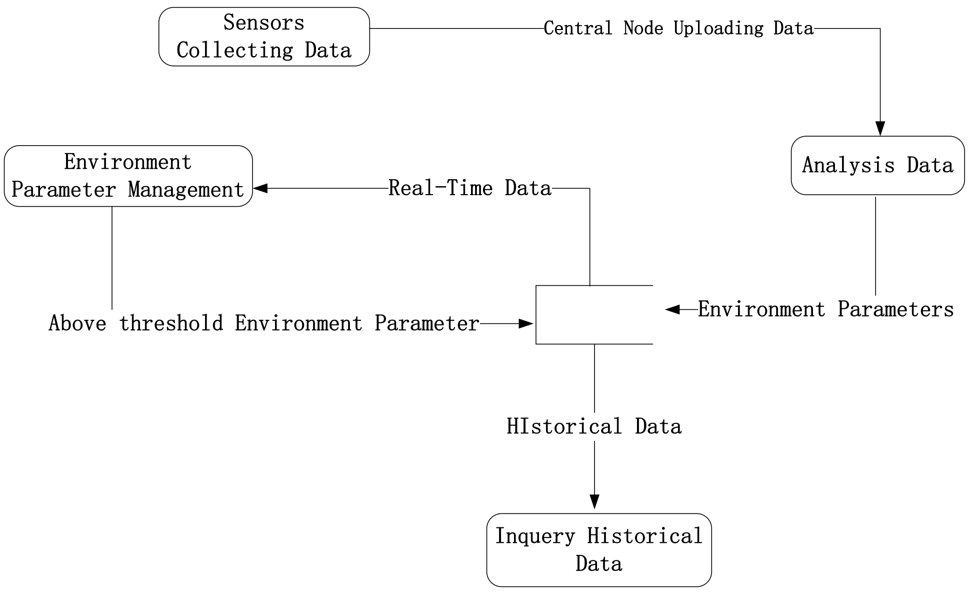


Figure 4. Environment Parameters Data Flow Diagram

Copyright ⓒ 2016 SERSC

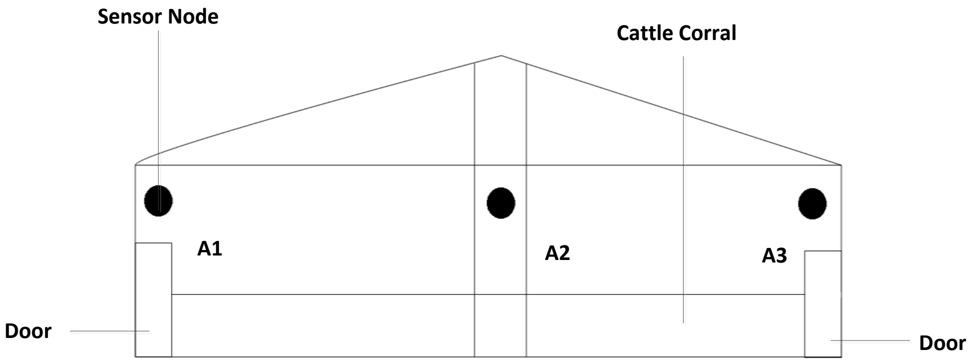
3. System Implementation and Test

As shown in Figure 5, the project team realized 3 sensor nodes based on the above system design. Each node has six types of sensors, including ammonia gas sensor, hydrogen sulfide sensor, illumination sensor, temperature and relatively humidity sensor and carbon dioxide sensor [11].

Figure 5. Sensors Node

3.1. Test Location

The system test was conducted on August 2015 in a certain farms of Heilongjiang province. Barn faces the south, the length and width of each barn are 100 meter and 15 meter respectively and every barn has double fences, and separation distance between two barns is 35 meter .There are around 150 cows here. The barn has 18 windows on the both sides of walls, which play the role of ventilation [11-13].



Notes：1.A1~A3 are the serial number of sensor nodes.
2.Black dots represent the sensor position.

Figure 6. The Position of Data Acquisition Nodes in Livestock House

3.2. Test Method

Testing time is in August, the outdoor temperature is about 25 degree centigrade, as shown in Figure 6, the three sensors were installed inside the barn, No. 1 is installed on the right side of the barn door, the height is 1.5 m. No. 2 nodes were installed on the middle of the wall in the barn, the height is 2 meters, No.3 node were installed on the walls of the south side of the barn, the height is 1.5 meters.

The control group data is measured by industry-grade environmental parameters monitor instrument, carbon dioxide, temperature and relatively humidity were measured simultaneously by using the device which is produced by XINTEST firm. Ammonia gas, hydrogen sulfides were detected meanwhile by the all in one industrial-level instrument. Illumination was recorded by is illumination recorder.

System test lasted for 7 days, the time interval of the node data uploading is 5 minutes, the database store the real-time data uploaded from central node. Then, due to the use of TCP protocol in network transport layer, the error caused by the loss of the bytes in the transmission process is negligible.

4. Results and Analysis

In this paper, the data were processed by SPSS software, the data of the experimental group and the control group were processed by t test, the P value was more than 0.05, and the difference was not significant [12].

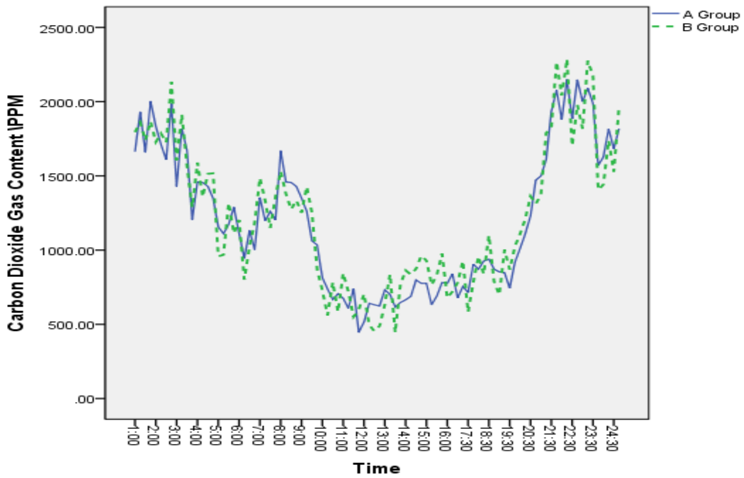


Figure 6. The Change of Carbon Dioxide Gas Content in 24h

According to the carbon dioxide broken line chart, the blue line represents the environmental parameters of the sensor node to collect the carbon dioxide data. The green line represents the data of the control group. In the LH, summer daytime and nighttime CO2 content are significant difference. Before 7:00 and after 20:00, the carbon dioxide concentration were above 1200ppm, and between the 22:00~3:00, the concentration of a few moments are lower than the national standard of the highest concentrations of 1500ppm, the rest are generally higher than the national standard.

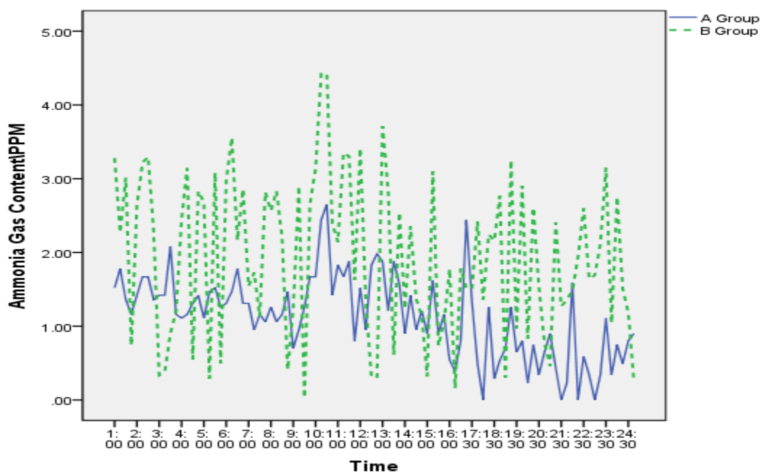


Figure 7. The Change of Ammonia Gas Content in 24h

 Copyright ⓒ 2016 SERSC

According to the ammonia gas broken line chart, the ventilation of the LH is pretty good, ammonia gas concentration is relatively low, and is always below 5.0 ppm in 24 hours. Between 9:00~13:00 and 16:00~17:00, the ammonia gas concentration is relatively high, according to the value of the control group, the highest index can reach 4.67 ppm, however it still below the national standard of the highest concentration of 25 ppm, meeting the standard of beef production.

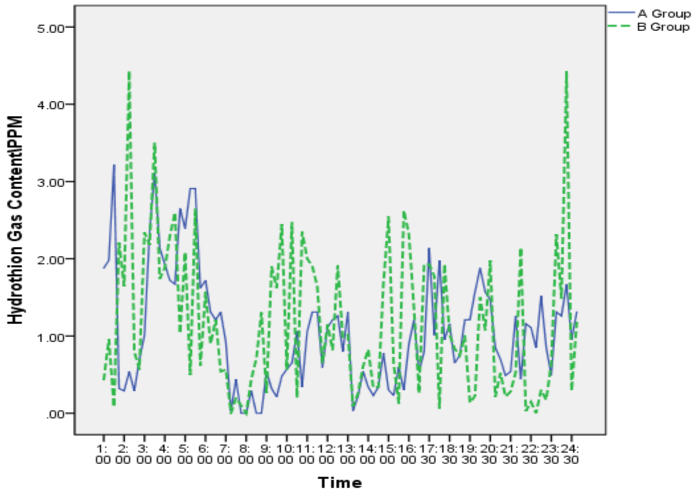


Figure 8. The Change of Hydrothion Gas Content in 24h

By the Figure 8, between 1:30~2:00 and 23:00~24:00, the hydrogen sulfide concentration reached a relatively high 4.52 ppm, during 7:00~8:00, it began to decline, reached a minimum of 0.16 ppm. After 8:00, it raised again. Almost at 23:00, the content floated up and down around 1.60. From 23:00 to 24:00, it soared to 4.66 ppm. Data fluctuation is relatively large, the value is frequently less than 5.00 ppm. Therefore, according to Chinese production standard (NY / T 388-1999) [13], the overall content is not enough to cause a negative impact on production in actual.

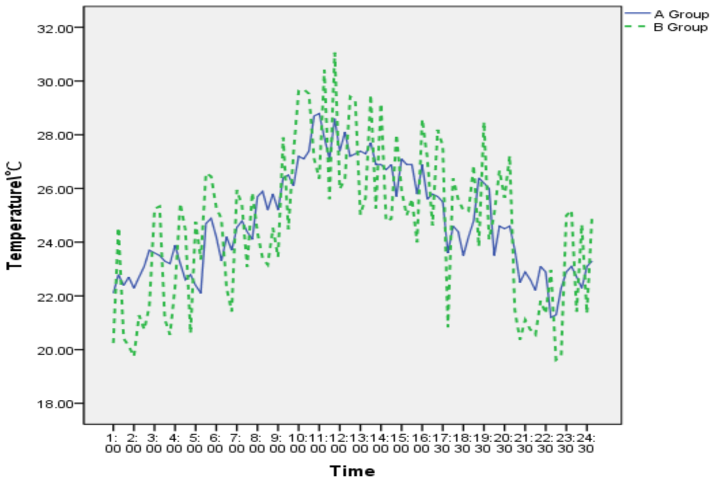


Figure 9. The Change of Temperature in 24h

Given the temperature is not low, according to Figure 9, the average maximum temperature reached 32 degrees Celsius, the average minimum temperature reached 19.5 degrees Celsius, and the tendency of overall indoor temperature is soar. During

10:00~15:00, temperature is above 25 degrees Celsius. That cooling conditions is a little poor.

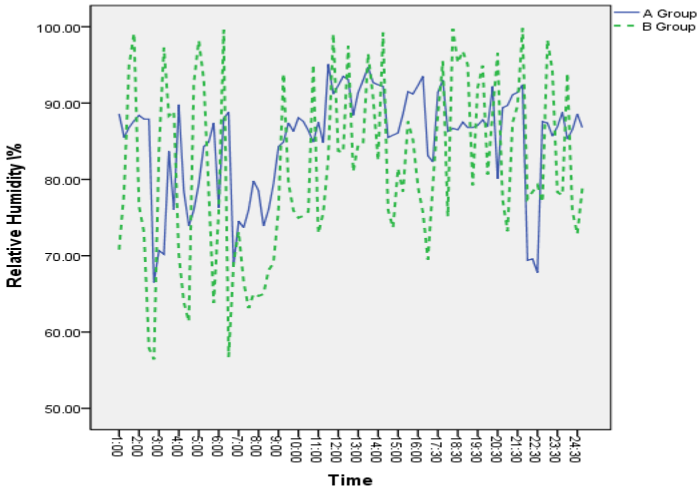


Figure 10. The Change of Relative Humidity in 24h

By relative humidity broken line chart, between 2:00~3:00 and 6:00~7:00, the relative humidity reached 60%, In the rest of the time, relative humidity is generally more than 70%, and far higher than 60% to 70% which is the most optimum relative humidity in LH, due to its poor production conditions, it failed to take necessary measures in high relative humidity. The overall humidity is too high, according to Chinese production standard (NY / T 388-1999)[13], which is not favorable to the production of beef cattle.

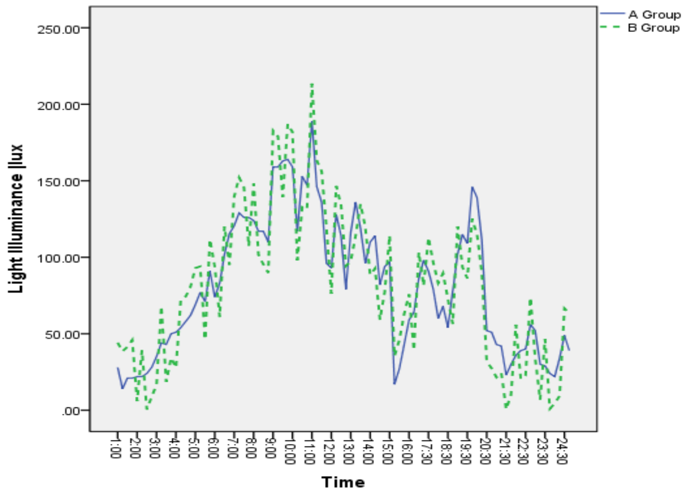


Figure 11. The Change of Light Illumination in 24

From the light data broken line charts, the illumination here varies greatly between day and night, it was affected by the artificial light source at night. The fluctuation of illumination is slightly .And according to Chinese production standard (NY / T 388-1999), in the daytime, illumination should not be lower than 50 lux [13], meeting the standard.

Copyright ⓒ 2016 SERSC

5. Conclusions

As livestock and poultry house scale up, and feeding density and the degree of refinement is much bigger than before, the demand for environmental factors in the breeding process is also growing strongly. In this paper, a set of intelligent monitoring system for the environmental parameters of LH was realized based on wireless sensor network. It could monitor real-time environmental parameters in LH, such as carbon dioxide and hydrogen sulfide and so on, threshold alarm and historical data query, and other functions.

Comparing with industrial-grade components high precision monitoring instruments, the error of sensor and wireless communication network is a little large. In the process of data fusion, a relatively elementary method is adopted. In the future work, we will carry on further research on the data fusion and other data processing [14-15], and improving the level of system performance.

Acknowledgments

The authors would like to acknowledge the financial support from key project of Heilongjiang Province of China(GC12B305), the key project of Harbin of Heilongjiang Province in China(2014AB1BN035), and early research of scientific achievements industrialization in university project of Heilongjiang Province of China(1253CGZH33).

References

[1] H. Yu, S. Liu, Q. Wang, X. Zhao, X. Huo and H. Wang, "Environment Multi-Parameters Monitoring System in Poultry-Livestock House", [J]. Journal of Agricultural Mechanization Research.no. 10, **(2013)**,pp. 178-180.

[2] E. Kokin, I. Veermäe, V. Poikalainen, J. Praks, M. Pastell, J. Ahokas and M. Hautala, "Environment, Health and Welfare Monitoring in Precision Livestock Farming of Dairy Cattle", [C]. Precision Livestock Farming - Papers Presented at the 3rd European Conference on Precision Livestock Farming, **(2007)**, pp. 171-177.

[3] Y. Xuhui, Z. Oineeuo, H. Genliane, Z. Bo, Z. Honexia, B. Shine and X. Wude, "Energy-efficient aquaculture environmental monitoring system based on ZigBee", [J]. Transactions of the Chinese Society of Agricultural Engineering, vol. 31, no. 5, **(2015)**, pp.183-190.

[4] C.E. Cugnasca, A.M. Saraiva, I.D.A. Nääs, D.J. De Moura and G.W. Ceschini, "Ad Hoc Wireless Sensor Networks Applied to Animal Welfare Research", [C]. 8th International Livestock Environment Symposium, ILES VIII. **(2008)**, pp.1009-1012.

[5] Xi Cong, "Research on Poultry House Environmental Monitoring System Based on ZigBee Technology", [D]. Jilin Agricultural University, **(2013)**.

[6] Rui Li, "Modern Farm Intelligent Monitoring System Research and Design", Southwest Petroleum University, **(2015)**.

[7] M. Samer, C. Loebsin, M. Fiedler, C. Ammon, W. Berg, P. Sanftleben and R. Brunsch, "Heat Balance an-d Tracer Gas Technique for Airflow Rates Measurement and Gaseous Emissions Quantification in Naturally Ventilated Livestock Buildings", [J]. Energy and Buildings, vol. 43, no. 12, **(2011)**, pp. 3718-3728.

[8] N. E. Firdaus and Z. S. Alvin, "Wifi Network Interface on Wireless Sensor Networks", [C]. 2014 Makassar International Conference on Electrical Engineering and Informatics, **(2014)**, pp. 54-58.

[9] R.Kannan, R. Kalidindi, S.S. Iyengar and K. Vijay, "Energy and Rate Based MAC Protocol for Wireless Sensor Networks", [J]. SIGMOD Record, vol. 32, no. 4, **(2003)**, pp. 60-65.

[10] D. Geer, "Users Make a Beeline for ZigBee Technology",[J]. Computer, vol. 38, no. 12, **(2005)**, pp.16-19.

[11] Z. Meng, F. Junlong and H. Yu, "Design on Remote Monitoring and Control System for Green-House Group Based on ZigBee and Internet", [J].Transactions of the Chinese Society of Agricultural Engineer-ing, vol. 29, no. 1, **(2013)**, pp. 171-176.

[12] S. Anjana, B. Anitesh and A. Whinston, "Understanding the Service Component of Application Service Provision: An Empirical Analysis of Satisfaction with ASP Services", [J].Management In-formation Systems, vol. 27, no. 1, **(2003)**, pp. 91-123.

[13] D. Xiaonan, W. Meizhi, C. Zhaohui, L. Jijun, Z. Junsheng and Z. Yueming, "Effects ofThermostatic Apparatus for Drinking Water and Roof-Lighting System on Improvement of Growth R-ate of Beef Cattle in Winter", [J]. Transactions of the Chinese Society of Agricultural Engineering, vol. 28, no. 24, **(2012)**, pp. 164-172.

Copyright ⓒ 2016 SERSC

[14] D. Smith and S. Singh, “Approaches to multisensory data fusion in target tracking A survey”[J].IEEE Transactions on Knowledge and Data Engineering, vol.18, no. 2, **(2006)**, pp.1696-1710.
[15] P. J. E.-Ambrosio, “Multisensor data fusion architecture based on adaptive Kalman filters and fuzzy logic performance assessment”, [C].Proceedings of the Fifth International Conference on Information Fusion Annapolis, **(2002)**, pp. 1542-1549.

Author

Weizheng Shen, (1977-), male, Ph.D., professor, mainly engaged in the research and application of information technology in agriculture.

 Copyright ⓒ 2016 SERSC