·农业生物环境与能源工程·

Intelligent monitoring system for laminated henhouse based on Internet of Things

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Abstract: At present, various single-parameter measuring instruments are used to measure environmental parameters, which have complicated operation and low detection efficiency. And the measuring points are too less to reflect the whole henhouse environment. To solve this problem, we proposed an intelligent monitoring system for laminated henhouse based on Internet of Things and designed a kind of sensor distribution topology its complex structure. It can realize the real-time online monitoring of environmental parameters of the henhouse with the local storage and remote transmission of measuring data. Through the web page or intelligent mobile APP, the users can make query to the henhouse environmental real-time data. The experimental result showed that air temperature, the concentration of CO_2, NH_3 and H_2S met the requirement of national environmental quality standard of livestock and poultry farm. But the light intensity, relative humidity, wind speed and PM10 were in the unreasonable range. Correspondingly, the corresponding optimization methods were given. In fact, we find that the system is suitable for the stable operation and accurate monitoring of henhouse environment, which application prospects are broad in large-scale livestock precision farming.

Key words: monitoring, networks, environmental engineering, embedded system, henhouse
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0 Introduction

With the increasing breeding scale of laying hens and the constraint of land resource in recent years, the breeding mode is changing from the ladder type cage to the laminated cage. Due to the increasing feeding density of laminated henhouse, the requirement of the environmental control technology is becoming higher and higher. Related research showed that adverse environment of henhouse can lead to the decrease of the production performance by 10%-20%[1-4]. Various single parameter measuring instruments were used to measure environmental parameters, which have complicated operation and low detection efficiency. And the measuring points were too less to reflect the whole henhouse environment. It was unable to realize convenient and real-time online monitoring[5-9].

To solve this problem, we proposed an intelligent monitoring system for laminated henhouse based on Internet of things and designed a kind of monitoring topology for its complex structure. It can realize the real-time online monitoring of environmental parameters of the henhouse with the local storage and remote transmission of measuring data. Through the web page or intelligent mobile APP, the users can make query to the henhouse environment real-time data. The monitoring experiments were carried out in a laminated automatic control henhouse with 8 layers, which contained 5

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million hens, of Anhui Sun Daily farm ecological food Co. Ltd in Tongling city. The henhouse environmental quality parameters were measured in different positions and the problems of breeding environment were analyzed to evaluate the henhouse environment scientifically and provide the corresponding optimization methods for the standard and automatic control of henhouse.

1 Overall design of monitoring system

As Fig.1, the system consisted of three parts: Data acquisition terminal, server and client[10-12]. The data acquisition terminal included a data collector and the sensors of air temperature, relative humidity, CO_2, light intensity, wind speed, NH_3, H_2S and PM10. And all the sensors were connected to the data collector by RS-485 bus. STM32F103VB(ARM 32-bit Cortex-M3 CPU), which realized the local storage and remote transmission of the data, was used as the core processor in the data collector. The server was developed based on the Web platform, SQL Server 2008 and ASP.NET. And it was used to receive data storage and processing. The clients contained two parts: Web query and Android mobile client[13-15].

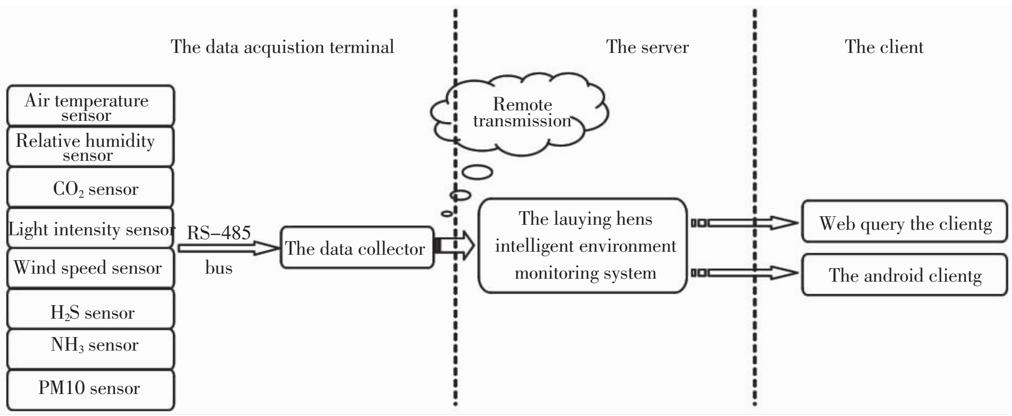


Fig.1 Framework of laying hens breeding intelligent monitoring system

1.1 Hardware design

The data collector adopted the low power consumption microprocessor STM32F103VBT6 as CPU. The system function modules included the RS-485 data acquisition, GPRS wireless data sending, real-time clock, SD card data storage, man-machine interaction and power management (Fig.2).

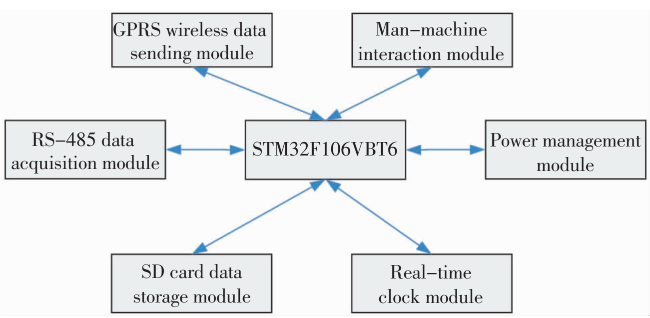


Fig.2 Data structure diagram of data collector

RS-485 data acquisition module was used to connect with the sensors of air temperature, relative humidity, light intensity, CO_2 (CG-01, Hefei Heinford Electronic Technology Co. Ltd). The measurement range of air temperature was -40-85 ℃, with the measurement accuracy of ±0.3 ℃. The measurement range of relative humidity was 5%-95%, with measurement accuracy of ±2%. The measurement range of light intensity was 0-100 lx, with measurement accuracy of ±1 lx. The measurement range of CO_2 was 0-1 000 mg/m^3, with measurement accuracy of ±10 mg/m^3). Wind speed was detected by using HD403TS2 (Italy DELTA Co. Ltd)with the measurement range of 0.08-5.0 m/s and measurement accuracy of ±0.2 m/s; NH_3 was detected by TM-AQ (Handan Yimeng Electronics Co. Ltd), the measurement range was $0-100\times10^{-6}$, with measurement accuracy of $\pm10^{-6}$); H_2S was determined by TM-LHQ(Handan Yimeng Electronics Co. Ltd)with measurement range of $0-100\times10^{-6}$, and measurement accuracy of $\pm10^{-6}$, PM10 was detected by DS-200 (Shenzhen Blue Control Co. Ltd)with the measurement range of 0-100 μg/m^3 and measurement accuracy of ±1 μg/m^3. All sensors have been calibrated before leaving the factory. GPRS wireless data sending module (Xiamen Caimore Communication Technology Co. Ltd)can realize the real-time transmission of environment data to the remote server. TCP transparent transmission mode with low power consumption were used. Combining with SD card data storage module and the real-time clock module, the environment data was recorded and stored in SD card. As most poultry farms were located in remote areas and the henhouse steel structure had the shielding effect to GPRS signal, GPRS signal in henhouse some places was poor, which maybe lead to the remote transmission data loss. This design can effectively solve this problem to avoid data loss[16-18].

The man-machine interaction module included a 4.3-

inch LCD and a keyboard. All environment parameters can be real-time displayed on the LCD, and the display module can be controlled. The LCD power supply can be cut off automatically after 5 minutes of electrical work, and the LCD screen can be restarted by a configuring automatic reset switch, which can reduce system power consumption and extend the LCD service life. The keyboard was used for setting of the periodic sampling, filtering and the controlling mode of data transmission. Power management module includes a DC12V 48AH large capacity cell group and the corresponding power conversion circuit.

After the completion of the monitoring system development, we also used the standard gases samples to calibrate the data collected by the system in order to ensure reliability and accuracy of data.

1.2 Software design

1.2.1 Software design of data collector

The system was developed based on the OS μCOS-II, which was a kind of open source, compact structure operating system with high efficiency, good real-time performance. Firstly, μCOS-II operating system was initialized. And then 6 tasks were set up according to the system function requirements, including the sampling period management task, GPRS data transfer task, data acquisition task, SD card data storage task, LCD display task and keyboard task (Fig.3), and their priority was high to low[19-20].

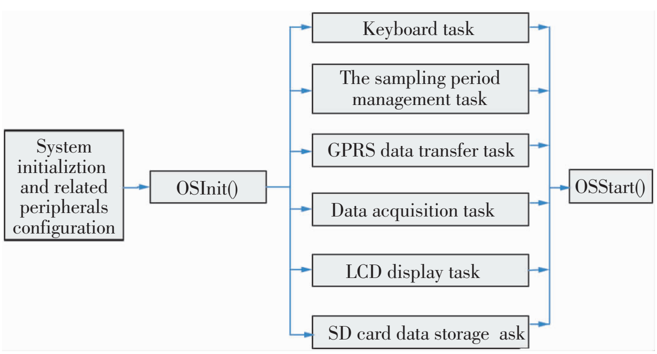


Fig.3 Software design diagram of data collector

The overflow of whole system was shown in Fig.2. The sampling period management task was used to control the sampling period of the system and the real-time clock RTC ALARM interrupt mechanism was used, which belongs to the interrupt level task with the highest priority. The GPRS data transfer task was responsible for the UART1 to transmit data to the GPRS module. In order to guarantee the reliability of data transmission, the priority was set to a higher priority. In the data acquisition task, each sensor is powered firstly, the task is hung 10 s in order to ensure the working states of the sensors were stable. And then the UART0 was started, querying each sensor real-time to collect the henhouse environmental parameters with polling mode which was placed in a DMA buffer for the use of the other task. The SD card data storage task was responsible for calling the sensor acquisition parameters and collection time. And then it was written to the SD card. LCD display task received the sensor data and real-time display output through the mail boxes (message)mechanism. The keyboard task was responsible for setting work mode of the system, such as enable GPRS module, sampling period, data filtering mode and so on.

1.2.2 Software design of monitoring system

The web server monitoring software was developed based on SQL Server 2008, ASP. Net and visual studio 2010 web platform. It realized the real-time storage of environmental parameters information, user management, safety inspection, forms and statements establishment. The server included two parts: The first part was the real time interaction between the server and the data collector; and the second part responded and processed the request of intelligent mobile client[21-23].

The Android mobile monitoring software was developed on Android development platform with Eclipse configuration. And the Java programming language was used. Through it, the henhouse environmental parameters can be viewed on the phone(Fig.4).

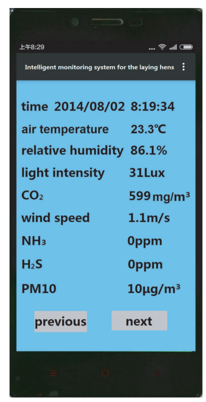


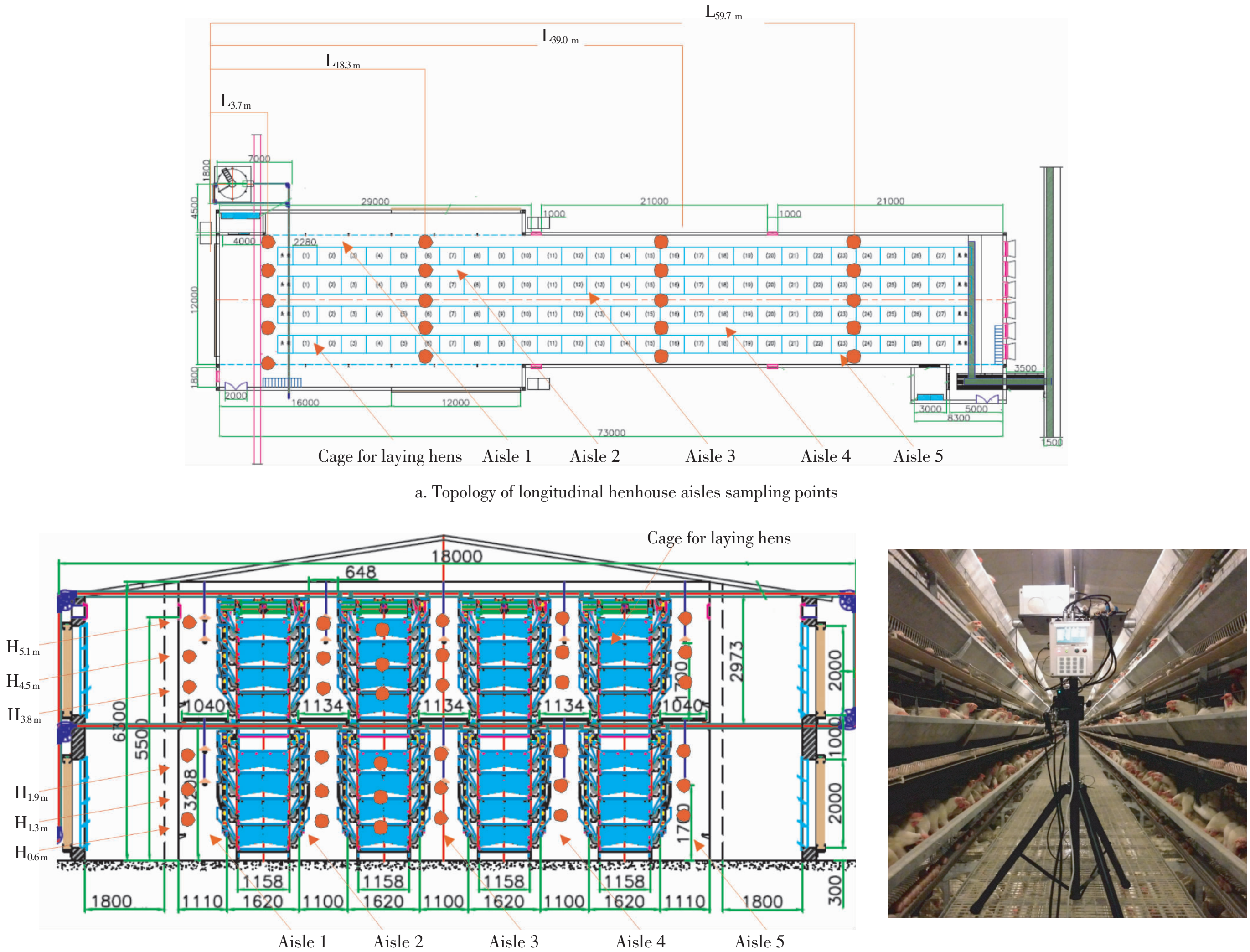
Fig.4 Monitoring interface based on Android mobile phone platform

2 Design of monitoring experiments

The monitoring experiments were carried out in a laminated automatic control henhouse with 8 layers, which contained 5 million hens, in Anhui Sun Daily Farm Ecological Food Co. Ltd in Tongling city from July 10 to September 7, 2014. The environmental control system was designed by Guangzhou Guangxing Poultry Equipment Croup Co. Ltd. The henhouse was 73.0 m long, 16.0 m wide and 6.3 m high. And it had four columns and five aisles. The cage in the henhouse used eight layers of stacked cages, which were divided into upper and lower four floors with the middle of the steel management network. The longitudinal damp curtain ventilation system was installed in the henhouse. Coop lighting adopted 11 W incandescent lamp with shade.

According to the spatial structure of laminated henhouse and the distribution of the hens coop, a kind of monitoring distribution topology was designed. From the damp curtain to the fan port, the air temperature, relative humidity, light intensity, CO_2, wind speed, NH_3, H_2S and PM10 in four points were monitored which were 3.7, 18.3, 39.0, 59.7 m($L_{3.7\ m}$, $L_{18.3\ m}$, $L_{39.0\ m}$, $L_{59.7\ m}$) of 5 aisles (Fig.5a), respectively. Meanwhile, 6 points of 0.6, 1.3, 1.9, 3.8, 4.5 and 5.1 m($H_{0.6\ m}$, $H_{1.3\ m}$, $H_{1.9\ m}$, $H_{3.8\ m}$, $H_{4.5\ m}$ and $H_{5.1\ m}$)(Fig.5b)from the ground were monitored each aisle (Fig.5c). The environmental parameters in each point were collected per one minute.

SPSS 20.0 was used for analysis of variance and multiple comparisons were done when the difference was significant with the least significant difference method(LSD method).



a. Topology of longitudinal henhouse aisles sampling points

b. Topology of transverse henhouse aisle sampling points

c. Installation map of data collector

Note: The round in the fig a, b were the sampling points.

Fig.5　Topology of henhouse aisle sampling points and installation map of data collector

3　Results and discussion

3.1　Analysis of data

Due to the high automation level of the henhouse experiment and good ventilation in summer, NH_3 and H_2S can not be detected. The results of henhouse environmental parameters from the damp curtain to fan port were shown in Table 1.

From table1, the farther distance from the damp curtain, the bigger the value of temperature, CO_2, PM10 and wind speed were. But relative humidity had a decrease trend. Light intensity was relatively uniform. Wind speed at the point of $L_{3.7m}$ was significantly lower than that of $L_{18.3m}$, $L_{39.0m}$ and $L_{59.7m}$(P<0.05).

With the increase of cage layer's height, the concentration of CO_2, relative humidity and PM10 were increasing. But the wind speed was decreasing. Light intensity at $H_{1.3m}$, $H_{1.9m}$ was higher than that of $H_{4.5m}$ and $H_{5.1m}$, and light intensity at $H_{1.3m}$ was significantly higher than that of $H_{0.6m}$ and $H_{3.8m}$. The temperature distribution of each cage layer was uniform. The relative humidity values at $H_{3.8m}$, $H_{4.5m}$, $H_{5.1m}$ were significantly higher than those of three lower measuring points. PM10 of $H_{3.8m}$, $H_{4.5m}$, $H_{5.1m}$ were 50% higher than the three points in the lower layer.

Table 1 Results of light intensity, relative humidity, temperature, PM10

Group	Light intensity/lx	Temperature/℃	Relative humidity/%	PM10/(μg·m^{-3})	CO_2/(mg·m^{-3})	Wind speed/(m·s^{-1})
$L_{3.7m}$	39.57±2.32a	26.62±0.12a	81.64±0.67a	1.66±0.32a	622.0±6.66a	0.08±0.03a
$L_{18.3m}$	34.65±0.99b	26.93±0.17a	81.57±0.68a	13.15±2.2b	749.6±19.12b	0.28±0.05b
$L_{39.0m}$	37.31±1.72c	27.37±0.19ab	80.58±0.80ab	13.56±1.2b	818.2±12.59c	1.49±0.09c
$L_{59.7m}$	37.33±1.45d	27.92±0.17b	79.03±0.79b	18.54±1.6b	933.4±14.33d	1.71±0.07c
$H_{0.6m}$	35.84±1.08a	27.09±0.22	79.44±0.90a	3.05±0.53a	685.4±20.84a	1.22±0.19a
$H_{1.3m}$	46.87±1.73bc	27.22±0.24	79.32±0.97a	4.40±0.83a	756.9±32.18ac	1.05±0.20ab
$H_{1.9m}$	40.46±2.33ac	27.51±0.28	78.87±1.03a	4.17±0.79a	783.6±34.91ac	0.90±0.19ab
$H_{3.8m}$	29.66±1.29d	27.05±0.19	82.45±0.69b	9.85±1.45b	809.7±26.11bc	0.73±0.15ab
$H_{4.5m}$	35.75±1.77ad	27.19±0.21	82.20±0.79b	11.88±1.70b	839.5±28.93bc	0.72±0.17b
$H_{5.1m}$	33.54±2.22ad	27.20±0.24	81.96±0.83b	10.67±1.53b	811.2±28.44bc	0.72±0.16ab

Note: Different lowercase letters in the shoulder of the same column in the same direction mean significantly different($P<0.05$).

3.2 Optimized proposals

Firstly, the concentration of CO_2 in the henhouse met the requirement of national environmental quality standard of livestock and poultry farm [24]. But the light intensity in the lower layer was higher than the upper layer of 7–10 lx. It mainly because that the light source above the aisle can irradiate through the aisle steel net and stack with lower four layers light source. It was recommended that reducing the number of the light bulbs, adjusting the spacing distance between light and replacing the 11W incandescent lamp with 5 W to make the light intensity with a uniform distribution[25-27].

Then the average temperature of the henhouse was 27 ℃, and temperature control was satisfactory. The relative humidity was high at the nearest points the damp curtain. And the wind speed at same points was only 0.08 m/s which was lower than the national environmental quality standard of livestock and poultry farm [28]. It can be ascribed to that the guider plate installed behind the damp curtain guide the cooling air to rise and meet with the hot air. It was recommended that adjusting the angle of the damp and reducing the open time and frequency of damp curtain to make the relative humidity and wind speed of the henhouse be in the reasonable range. Additionally, the fan mode was regulated to reduce PM10 in the upper air.

4 Conclusions

An intelligent monitoring system for laminated henhouse based on Internet of things and a kind of monitoring topology for its complex structure were designed in the paper. It can realize the real-time online monitoring of environmental parameters of the henhouse with the local storage and remote transmission of measuring data. Through the web page or intelligent mobile APP, the users can make query to the henhouse environment real–time data. The monitoring experiments were carried out in a laminated automatic control henhouse with 8 layers, which contained 5 million hens. The result shows that the air temperature, CO_2, NH_3 and H_2S meet the requirement of national environmental quality standard of livestock and poultry farm, but light intensity, relative humidity, wind speed and PM10 in the unreasonable range. The corresponding optimization measures are given. Practice shows that the system is suitable for the accurate monitoring of henhouse environment, which has broad application prospects in large-scale livestock precision farming. More precise measurements and reasonable monitoring topology for laminated henhouse should be researched in further work. And the monitoring solution for different types of poultry should be considered.

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基于物联网的层叠式鸡舍环境智能监控系统

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摘　要:由于层叠式鸡舍的饲养密度大,因此对养殖环境要求高,目前,对层叠式鸡舍环境监测多采用功能单一的检测仪器,操作复杂,且监测的位置点较少,很难反映层叠式鸡舍环境的整体情况,该文研制了一种基于物联网技术的蛋鸡养殖环境智能监控系统,针对层叠式鸡舍复杂结构,设计了一种监测布点的拓扑结构,可以实现对层叠式鸡舍环境参数的实时在线监测,可以对采集数据进行本地存储记录和远程发送,用户可以通过网页或智能手机 APP 进行鸡舍环境数据实时查询。试验发现鸡舍内温度、CO_2、硫化氢和氨气浓度分布符合畜禽场环境质量标准,而光照强度、风速、湿度和 PM10 局部分布不合理,并给出了相应的优化措施。实践表明,该系统运行稳定、测量数据精确,适合对鸡舍环境进行精准监测,在规模化畜禽精准养殖方面具有广泛的应用前景。

关键词:监测;网络;环境工程;嵌入系统;鸡舍