Based on STM32F103 cowshed environment intelligent control system

Xuhai Wang\(^1\text{-}^a\), Weiguo Li\(^2\text{-}^*\), Lili Wang\(^1\text{-}^b\), Yi Zhang\(^1\text{-}^c\), He Zhao\(^1\text{-}^d\)

\(^1\)School of Mechanical Engineering, Inner Mongolia University of Technology, Hohhot, 010051
\(^2\)Innovative Training Center of Engineering Training and Teaching Department, Inner Mongolia University of Technology, Hohhot, 010051

*Corresponding author e-mail: wxh037100@163.com, \(^a\)1018740412@qq.com, \(^b\)992123503@qq.com, \(^c\)1287664425@qq.com, \(^d\)1012025647@qq.com

Abstract. The environment of the barn affects the growth, health, reproduction and fattening of the cattle. In order to control the environment of the barn, an intelligent control system based on STM32F103 was designed to monitor and control the temperature, humidity and toxic and harmful gases such as SO2 and NH3. The system adopts STM32F103 as the control core; air pollution sensor MQ135, humidity sensor DHT11, temperature sensor DS18B20 is the system data acquisition device; air purification box (pump, condenser, heating plate, fan) is the system execution device, PC end data analysis software. The experiment was carried out in Mengniu dairy farm in Shengle Economic Development Zone, Hohhot City. The results show that the system can monitor and control various environmental factors stably and reliably.

1. Preface

With the government's economic and technical support for the livestock industry in rural areas, the development of cattle farming in rural areas has been promoted. Because the barn is a relatively closed space, the cattle's breathing, excretion and the decomposition of organic matter in the production process, the harmful gas components are much more complicated than the external environment, so the environmental monitoring and regulation of the barn becomes a very important link. The study found that an unfavorable barn environment would result in a 10% to 20% reduction in cattle production capacity, which greatly affected the health and productivity of cattle. Production practices and related scientific studies in the aquaculture industry have shown that temperature, humidity, illuminance and harmful gas concentrations in the barn have an impact on the growth, health, reproduction and feed utilization of the cattle. Therefore, it is very necessary to design an accurate and real-time monitoring and regulation of these environmental factors in the barn, to ensure that cattle live in a suitable environment [1].

Compared with developed countries, the production level of China's livestock and poultry breeding industry is still relatively backward. Most of the farms in China still rely on artificial breeding. The monitoring of the cattle house environment can only be done by manual ventilation and regular treatment of cattle excrement. The efficiency of the cattle house environment detection is low and it cannot be processed in a timely and efficient manner, which limits the development of the aquaculture
industry to some extent. Therefore, the use of advanced intelligent control systems for scientific and optimal management of the aquaculture industry is very necessary. In recent years, the impact of the cowshed environment on cattle has been taken seriously. For example, Tianjin Agricultural University conducted research on the cattle house environmental control system based on the Internet of Things; Hebei University of Science and Technology conducted research on how to regulate the poultry house environment [2-3]. Based on the above background, this paper designs a system based on STM32F103 cowshed environmental intelligence control system.

The system uses STM32F103 MCU as the controller core; air pollution sensor MQ135, humidity sensor DHT11, temperature sensor DS18B20 is the system data acquisition device; air purification box (pump, condenser, heating plate, fan) is the system execution device, the cowshed Real-time monitoring and regulation of temperature, humidity, wind speed and environmental factors such as toxic and harmful gases such as CO2 and NH3.

2. Control system overall design and working principle

2.1. Overall system design

The system consists of four parts: the bottom control unit, the data acquisition device, the system execution device, and the host computer software. The bottom control unit includes: STM32F103 MCU, reset circuit, clock module, alarm, button module, LCD12864 liquid crystal display, power module, mainly to achieve control decision, process data, store data, limit alarm, parameter design, data through USART The transmission function is medium in PC; the data collection device includes: air pollution sensor MQ135, humidity sensor DHT11, temperature sensor DS18B20, which mainly realizes functions of collecting indoor environment data, transmitting collected data to the bottom control unit, etc.; system execution device includes: heating The film, the water atomizing device, the condensing pipe, the fan, the water tank and the water pump are mainly used to control various environmental factors in the cow house. The PC software is based on the development of Windows system, mainly to analyze the data transmitted from the underlying control unit, and to make a line diagram of the environmental change of the cowshed. The structural block diagram of the system is shown in Figure 1.

![Figure 1. Block diagram of the cowshed environment intelligent control system](image-url)
2.2. How the system works

(1) Parameter setting

According to the "Environmental Quality Standards for Livestock and Poultry Farms", the ammonia reference content of the cowshed intelligent control system is set to 26ppm, the reference content of sulfur dioxide is 764ppm, the temperature reference content is 10-15 °C, and the humidity is relative by the independent button and LCD12864 liquid crystal display. The reference amount is 80%, and the wind speed reference amount is 1.0 m/s [4].

(2) Data processing

The data collected by the multiple sensors distributed in different positions in the cowshed is transmitted back to the bottom control unit through the AD data receiving module, and the bottom control unit applies the weighted fusion algorithm to the data collected by the sensors of the same type of sensors at different positions. The data is processed to avoid the inaccuracy of the data collected by the individual sensors affecting the judgment of the entire system, and to ensure that the collected values are consistent with the environmental values in the barn environment. The processed data is compared with the parameters set between the two, and if the indicators do not meet the predetermined parameters, the corresponding actuators are driven to adjust the environment of the barn.

(3) How the executive works

The actuator is mainly an air purifier, and the structure of the air purifier is shown in Figure 2. When the ammonia content of the feces in the barn exceeds a predetermined value, according to the characteristic that the ammonia gas is easily soluble in water, the fan at the end of the air purifier reverses to draw air into the air purifying tank. In the air purifying tank, the water pump sucks the water into the atomizing device, and the atomizing device sprays the water mist into the purifying tank to increase the contact area between the water and the inhaled gas to make the ammonia gas dissolve as much as possible. In order to prevent the ammonia gas dissolved in the water mist from volatilizing, it is condensed through the condenser, and finally flows back to the water tank with the water circulation system, and the purified air is returned to the cowshed from the end of the tank. When it is detected that the humidity in the barn exceeds a preset value, the heater chip starts to work and then the forward fan is rotated forward to lower the humidity in the air. When the barn is too dry, the water is atomized by a water atomizing device and then discharged from the end fan into the barn to adjust the humidity in the barn. The control of the actuator adopts a closed-loop control method to speed up the gas circulation speed and effectively adjust various indoor indicators [5-6].

![Figure 2. Air purification box](image)

1. Heating sheet 2. Box 3. Water atomizing device 4. Condensing tube 5. Fan 6. Water tank 7. Water pump
3. Control system hardware design

3.1. Underlying controller
The controller selects STM32F103RBT6 single-chip microcomputer as the main control chip. The chip has the advantages of fast running speed and low power consumption. The power supply mode mainly uses the AMS1117 chip to regulate the voltage VCC3.3, considering that the backup register is not lost due to power failure. The button battery and the VCC3.3 hybrid power supply power to the chip VBAT pin. The alarm selects the active buzzer. When the buzzer is powered on, it will oscillate and it is convenient to control. The indicators are the power indicator and the button indicator. The USB to serial port is selected by CH340G and has been tested and tested. The chip's reset is a low-level reset, so the designed circuit is also low-level reset. In addition, the controller also provides a controller startup mode setting port for convenient control. The download circuit selects the JTAG download circuit, which not only downloads the code but also debugs and is very fast [7-8]. The schematic is shown in Figure 3.

![Figure 3. Master controller schematic](image)

3.2. Data acquisition unit
The data acquisition unit is composed of an air pollution sensor MQ135, a humidity sensor DHT11, and a temperature sensor DS18B20.

The air pollution sensor uses MQ135. The sensor works on the principle that the tin dioxide has a low conductivity in clean air and high conductivity in polluted air. When there is a polluting gas in the environment where the sensor is located, the conductivity of the sensor increases as the concentration of the polluting gas in the air increases. The MQ135 gas sensor has high sensitivity to ammonia, sulfide and benzene vapor. The circuit shown in Figure 4 can be used to convert the change of conductivity into an output signal corresponding to the gas concentration. The concentration of different pollutant gases corresponds [9]. The electrical signal is shown in Figure 5.
The DHT11 digital temperature and humidity sensor is a temperature and humidity composite sensor with a calibrated digital signal output. It uses dedicated digital module acquisition technology and temperature and humidity sensing technology to ensure high reliability and excellent long-term stability. The circuit schematic is shown in Figure 6.

DS18B20 Single-line digital temperature sensor, that is, "one-line device", multi-point networking function Multiple DS18B20 can be connected in parallel on a single single line to achieve multi-point temperature measurement. Measurement parameters configurable The DS18B20's measurement resolution can be programmed from 9 to 12 bits. Power-Down Protection The DS18B20 contains an internal EEPROM. After the system is powered down, it can still save the resolution and alarm temperature settings [10].

3.3. Actuator module
The actuator consists of an air circulation system, a condensing system, a hazardous gas treatment system, and a drying system. The actuators use switching control. Since the GPIO port of the STM32F407 MCU cannot directly drive the device, an optocoupler, a Darlington drive circuit and a relay are added between the GPIO port and the actuator, and the optocoupler is used to isolate the current fluctuation of the high-voltage device during the startup and shutdown process. The effect of stability; Darlington drive circuit enhances the output signal of GPIO port, drives relay, controls actuator action [11-12], and the circuit schematic is shown in Figure 7.
4. Control system software design

The cowshed environment intelligent control system adopts a modular design method, and each module is independent of each other and cooperates with each other. The system is mainly composed of main program, sensor data acquisition subroutine, and host computer software design. Considering that C language has a wide range of applications, can be ported, and is suitable for a variety of operations, the system is mainly written in C language.

4.1. Main program design

First, the system is initialized, and various indicator parameters in the environment are set by pressing a button to declare other subroutines. Then, the data collected by the data acquisition system is processed, and the processed result is compared with the initially set index parameters. If the collected value exceeds the set value, the MCU gives the actuator module signal and turns on the execution device. The actuator is turned off until the data of the acquisition is lower than the set parameters. The block diagram is shown in Figure 8.

The data processing method mentioned mainly adopts the method of data fusion. Suppose there are n sensors that measure the same factor in the system. Sensors s1, s2, ..., sn evaluate the state of the same target. The local state estimate of the i-th sensor at time k is si, (i=1, 2, ..., n). It is assumed that there is an unbiased estimate, and the local estimation errors of any two sensors are not related to each other. Let the weights of the respective sensors be w1, w2, ..., wn, respectively, and the conditional values of the fusion and the conditions for the weights to be satisfied are:

\[
\bar{x}_k = \sum_{i=1}^{n} w_i \bar{x}^i_k, \quad \sum_{i=1}^{n} w_i = 1
\]  

The weighted average fusion algorithm usually uses the mathematical average method, that is, the myopia of each sensor is equal, and the equal weight is w, and according to the formula:

\[
w = \frac{1}{n}
\]

The state values after partial fusion are:

\[
\bar{x}_{k} = \sum_{i=1}^{n} w_i x^i_k = \frac{1}{n} \sum_{i=1}^{n} x^i_k
\]

Finally, the result of the calculation is used as the final reference quantity of the signal to call the decision subroutine scheme to realize the control of the cowshed environment. The calculated result is taken as the final reference quantity of the signal.
4.2. Sensor data acquisition program
First, the temperature, humidity, and environmental pollution sensors are initialized, and then the data collected by the sensor is read separately, and finally the read result is packaged in the form of a variable for the main program to call. The program flow chart is shown in Figure 9.

4.3. Design of human-computer interaction system
The human-computer interaction system is mainly for setting various index parameters of the control system. The program flow chart is shown in Figure 10.
5. System performance test
The system test chart is shown in Figure 11. A plastic cloth is used to build a relatively closed space to simulate the barn. Then, several chemical materials such as ferrous sulfide, calcium carbonate and calcium hydroxide are reacted to produce a certain amount in a closed space. Ammonia and sulfur dioxide are used to simulate the environment in the barn. A plurality of air pollution sensors, humidity sensors and temperature sensors of the system are respectively arranged at different positions in the simulation space, and the temperature, humidity and toxic and harmful gases SO2 and NH3 in the space are monitored. When the indicators in the environment are detected to exceed the set value, they will be regulated by the execution device. The test results are shown in Fig. 12. The contents of SO2 and NH3 in the barn are controlled to fluctuate within a relatively low content range, and the temperature fluctuates within a range of 10-15 °C.

![Figure 11. System simulation test chart](image1.png)

![Figure 12. System test result chart](image2.png)

6. Conclusion
In order to monitor the environment of the barn easily and conveniently, the growth, health, reproduction and fattening of the cattle are not affected by the environment. The cowshed environment intelligent control system was designed. The system uses STM32F103 chip as the main controller, and uses LCD12864 LCD screen and independent buttons as the human-computer interaction design to ensure the stability and reliability of the system while reducing the development cost. A multi-sensor data fusion method is adopted in data acquisition to ensure the reliability of the obtained data. The test results show that the system has low cost, low power consumption and simple networking, and can effectively and accurately monitor the environmental factors in the barn.

Acknowledgments
This work was funded by the Inner Mongolia Autonomous Region Higher Education Research Project (NJZY18081).

References
[1] Li Dong. Establishment of Good Agricultural Practice (GAP) in China's dairy farms and its application to the production and quality of raw milk [D]. Xinjiang Agricultural University, 2006.
[2] Samantha J. Ingram, Charlotte L. Kirkdale, Sian Williams et al. Moving anticoagulation initiation and monitoring services into the community: evaluation of the Brighton and hove community pharmacy service [J]. 2018, 18 (1).
[3] Ahmad Ali, Yu Ming, Sagnik Chakraborty et al. A Comprehensive Survey on Real-Time Applications of WSN [J]. Future Internet, 2017.
[4] Li Weihua, Wei Wei, Li Wenshun, Wei Chunbo, Ding Fujun, Chen Yuying. Design of multi-parameter acquisition and monitoring system for livestock house environment [J]. Journal of
Hu Beixia, Huang Yanyan, Lu Xishan, et al. Study on the surveillance of Newcastle disease and influenza virus in large-scale farms [J]. Jiangsu Agricultural Sciences 2008 (6): 205-206.

Zhao Jianhua. Design and implementation of wireless monitoring system for poultry house environment [D]. Northeast Forestry University, 2011.

Guan Hui, Xu Yulei. A Dynamic Fish Health Monitoring System Based on Machine Vision [J]. Internet of Things Technology, 2019, 9 (10):13-14+17.

Mauro Cannistraro, Giuseppe Cannistraro, Roberta Restivo. Environmental monitoring of sacred artworks – A case study for the search for an index of correlation between particle concentration and mass of fine dust [J]. Thermal Science and Engineering Progress, 2019, 14.

Zuo Zhiyu, Zhu Minmin, Mao Hanping, Tan Jie, Tang Xueping, Zhang Wenzhong, Zhao Chang. Development of Intelligent Control System Based on STM32F407 Micro Plant Factory [J]. Journal of Agricultural Mechanization Research, 2019, 41 (10):213-218+ 248.

Ding Qingfeng, Wang Liyao. Design of human health monitoring system based on composite sensor [J/OL], 2019(11): 82-84+88[201910].

Gao Zhongxia, Zhu Fengwu, Tu Chuanchuan, Han Guanghui. A Poultry House Environmental Monitoring System Based on Wireless Sensor Network (WSN) [J]. Journal of Agricultural Mechanization Research, 2012, 34 (05):139-142+146.

Simmons Courtenay K, Wiedmann Martin. Identification and classification of sampling sites for pathogen environmental monitoring programs for Listeria monocytogenes: Results from an expert elicitation. [J]. Food microbiology, 2018, 75.