Dynamic weighing system based on Internet of Things technologies

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Abstract: This paper studies and implements dynamic weighing system based on the Internet of Things (IOT) technology, which is used to detect the weight changes of animals easily and conveniently, in order to achieve the purpose of accurate feeding. The system is mainly composed of dynamic gravity data acquisition subsystem, RFID identification, network communication, web management, terminal database and BP neural network. The weight of animals is collected in real time, and the purpose of precise feeding is realized through the dynamic accurate measurement and storage of the animal weight. The system is simple, practical and stable.

1. Introduction
As a major industry in China, animal husbandry is one of the bases of national economic development. At present, various intelligent breeding equipment needs to be improved in automation and intelligence, and there is still a certain gap between the precise control of breeding process and that of foreign countries. How to achieve targeted and precise feeding mode through monitoring the weight of each animal is conducive to effective scientific feeding management and effective feed saving [1]. Therefore, how to achieve dynamic and accurate weight monitoring in the process of animal breeding is one of the key points to solve the problem.

In recent years, with the development of monitoring technology, intelligent weighing system is mainly applied in three fields [2]: The first category is mainly applied in the field of material circulation, such as logistics companies, supermarkets, mines and other industries where materials are frequently in and out. The second type is mainly used in the industrial production field. For example, chemical plants, food plants and other plants need to mix different ingredients according to a certain ratio. At this time, intelligent data collection is needed to process and transmit information. The third kind is mainly applied in the management level of enterprises, which is the extension of the second kind of application. For example, in some batching production enterprises, the intelligent weighing system runs through the raw material procurement, production, sales, management and other aspects.

With the development of global e-commerce, the development of the logistics industry is strong, and about 70% of the world's goods need to go through the weighing process. The requirements for the weighing system are different due to different application environments [3]. How to efficiently and accurately weigh is the challenge of various weighing systems. This paper mainly studies how to
conveniently carry out real-time and accurate monitoring of animal weight in the animal feeding environment. This study uses the existing dynamic weighing theory to design a convenient and practical dynamic weighing system.

2. General design of system

2.1. System function design

2.1.1. System framework.

The dynamic weighing system consists of the following six subsystems: gravity data acquisition subsystem, network communication subsystem, web management subsystem, database subsystem, data processing subsystem, and RFID identification subsystem.

![Dynamic weighing system diagram]

The gravity data acquisition subsystem collects the weight of the moving object by adopting the gravity sensor of the point array layout. The network communication subsystem stipulates the specific protocol and the related interface standards for communication between the parts of the system to ensure the stable interaction. The database subsystem is responsible for storing the data collected by the gravity data acquisition subsystem to ensure the persistence of the experimental data; The data processing subsystem optimizes the data collected by the gravity data collection subsystem through the corresponding algorithm. The web management subsystem is responsible for the visual management of the data collected by the gravity data acquisition subsystem, which can be used to operate the background data and related visual presentation through the web management subsystem. The RFID identification subsystem can distinguish different individuals in the experiment through the ear tag and accurately control the individual data.

2.1.2. System Modbus interface design.

Modbus protocol is a de-facto standard protocol in industrial automation. As the size and complexity of industry systems increase rapidly, the importance of real-time communication protocols arises as well[4]. And Modbus RTU is a simple and robust master-slave protocol that accepts the integration of a master with up to 247 slaves into a bus topology[5], and its physical interface complies with the specifications of RS-485 and RS-232.

Universal Serial Bus (USB) is a new personal computer interconnection protocol, developed to make the connection of peripheral devices to a computer easier and more efficient. It reduces the cost for the end user, improves communication speed and supports simultaneous attachment of multiple devices (up to 127) RS232[6]. The system adopts HIRS-10-C10-FMMdbus to carry out A/D conversion of gravity sensor data, convert analog quantity into digital quantity, and transmit it through RS-485 or RS-232. The design is of system hardware.

2.2. Hardware system overview

The hardware platform is mainly composed of object detector, namely weighing platform, Modbus signal conversion circuit, hostcomputer, display, ground inductor, etc.

When the detected object moves on the weighing platform, it first processes the measured data through the hardware system. The initially measured weight signal needs to be converted into a...
voltage signal by the pressure sensor, and the converted signal is very weak, almost to millivolt level. Therefore, the data amplification circuit is needed to amplify the signal size suitable for the hardware system to process. The collected data is analog signal, and the analog quantity is converted into digital quantity by A/D conversion circuit through Modbus digital junction box and sent to the host for software processing.

The design of the process flow of the system is as follows:

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The object is of detectors

The weighing sensor

Signal is Modbus conversion circuit

ZigBee wireless transmission

Host

Data storage

Data processing

Web management system
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Figure 2: Weighing system is processing flow

2.3. Introduction of each hardware subsystem of the system

2.3.1 Gravity data acquisition subsystem

ZigBee is a specification formalized by the IEEE 802.15.4 standard for low-power low-cost low-data-rate wireless personal area networks[7]. It is very suitable for the requirements of data acquisition by hardware in the project, so ZigBee is chosen as the wireless transmission channel. The weighing sensor is actually a device that converts mass signals into measurable electrical and output it. In the process of weighing, the accuracy of the sensor will decline with the development of time. For the sensor itself, the performance of the sensor used in different environments varies greatly, and the price difference is also large [8]. Factors influencing the long-term stability of the weighing sensor include aging, fatigue and environment. As the operating environment of this system is in the field of animal husbandry and breeding, the environmental cleanliness is relatively poor and the humidity is relatively high. Therefore, the requirements on the operating environment of the sensor are relatively high, and the reliability and stability of the sensor should be taken into consideration.

The gravity sensor is a single-point acquisition device. The collected data cannot be directly obtained by weight, and the value data can only be obtained by special processing. Moreover, the collected object is active. Therefore, this paper proposes a multi-point acquisition array layout, as shown in the following figure:

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The weighing sensor 1

...........

The weighing sensor n

The weighing sensor 2

...........

The weighing sensor n+1

Coordinator
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Figure 3: The composition is of gravity data acquisition subsystem
2.3.2. RFID identification subsystem
Existing RFID read-write system was based on cable transmission, there are the positioning of the read-write device, poor flexibility short data transmission distance, higher cost of its equipment, and other short-comings in its design[9]. wireless signal transmission is introduced in order to improve the transmission distance. For example, for the RFID chip in the 2.4ghz transmission band, the distance can be up to 10 meters [10]. RFID is combined with ZigBee network. RFID tag relies on wireless signal for identification. The identification of payload information P can be customized according to actual conditions, such as P={ID, gender, weight value}. Applied to this project, the independence of individual information is guaranteed, and the precise control of each individual is realized. As shown in the following figure:

![Figure 4: RFID chip data receive process](image)

2.3.3. Network communication subsystem
Zigbee protocol stack is the specific implementation form of the protocol. The protocol stack is an interface between the protocol and the user. Developers use the protocol stack to realize wireless data sending and receiving. After the data collected by the sensor is transmitted to the digital junction box, the digital junction box transmits the corresponding signal to the RS-485 transposition serial interface equipment. The RS-485 serial interface is adopted to design the conversion circuit, which realizes the conversion of the collected data from analog signals to digital signals in the standard ModbusRTU format, and transmission through ZigBee wireless network.

The network communication subsystem is shown as follows:

![Figure 5: Network communication architecture](image)

3. System software design

3.1. Software system overview
The hardware system transmits the collected data to the upper computer through ZigBee wireless network. The upper computer sends the collected data to the database management system for storage. Then the collected data is preprocessed and divided into train set and test set. The BP neural network is trained by using the train data, and a set of BP neural network weights that meet the accuracy requirements are obtained, and a reasonable network model is established.

3.2. Introduction of software subsystem
3.2.1. Web management subsystem
The Web management subsystem is developed in PHP based on B/S architecture. The function of the Web management subsystem is to manage the data collected by the sensor uniformly, and enable the data to be displayed in the browser for the convenience of data analysis when modeling.

3.2.2. Database subsystem
In order to facilitate data processing, this system adopts MySQL database. The subsystem mainly completes the storage of the raw data collected by the sensor, the training dataset and test dataset for the modeling service.

Meanwhile, in order to improve the storage efficiency of the database, we take the following measures to optimize the database:

1. While the database of large product requires high reliability and concurrency, InnoDB as the default MySQL storage engine is a better choice than MyISAM.
2. The schema, tables, and fields of the organization database are used to reduce the I/O overhead, keep related items together and plan ahead, so that performance can be maintained at a high level as the volume of data grows. Design the data table need to minimize its space, the table's primary key as short as possible.
3. Increasing the buffer pool size at InnoDB allows queries to be accessed from the buffer pool rather than via disk I/O. The buffering indicator is adjusted to the best level by adjusting the system variable innodb_flush_method.
4. Periodically review slow query logs and optimize the query mechanism to take full advantage of caching to reduce disk I/O. Use the OPTIMIZETABLE statement to reorganize the table and compress any space that might be wasted.

3.2.3. Data processing subsystem
The data processing subsystem is the core module of the system. In this module, the data collected by the system is processed through the BP neural network. Through the processing of the training dataset, a reasonable network model is established, to achieve better test performance.

In the process of dynamic weighing, dynamic weighing is mainly affected by the value of five sensors, therefore, five values were selected as input parameters. Dynamic weighing is to estimate the static weight, so the static weight is selected as the output parameter, thus forming a BP neural network with multiple inputs and single outputs. We first learned its scope based on the empirical formula, and then used the train dataset to repeatedly train the BP neural network, then analyzed and considered the training effect of each network, and finally obtained the number of nodes in the hidden layer of BP neural network. The empirical formula is as follows:

\[ H = \sqrt{I + O} + a, \quad a \in [1,10] \]  

(1)

Where, \( H \) is the number of nodes in the hidden layer, \( I \) is the number of nodes in the input layer, \( O \) is the number of nodes in the output layer, and \( a \) is a constant.

The BP neural network model is established as follows:

![BP neural network model](image)

Figure 6: The model is of BP neural network

In the figure, \( X_1 \) to \( X_5 \) are the input parameters of BP neural network, them are the values corresponding to the five sensors. \( Y \) is the output parameters of BP neural network, namely static weight, and \( W_1 \) is the weight vector matrix connecting the input layer to the hidden layer. \( W_2 \) is the
weight vector matrix connecting the hidden layer to the output layer. In the BP neural network designed in this system, W1 is the vector matrix of 5x10 and W2 is the vector matrix of 10x1.

Through repeated training, the hidden layer chooses tansig, a hyperbolic tangent function, as the activation function, while the output layer chooses purelin, a linear function, as the activation function. The expressions of the two activation function are as follows:

$$f(x) = \frac{1-e^{-x}}{1+e^{-x}} \quad (-1 < f(x) < 1) \quad (2)$$

$$f(x) = \begin{cases} -1, & x \leq -1 \\ x, & -1 < x < 1 \\ 1, & 0 \leq x \end{cases} \quad (3)$$

In order to ensure the stability of the training process, their selection also affects the training process of the whole network. If it is too large, the adjustment quantity of the weight will become larger, which will produce shock phenomenon and make the network unstable. Otherwise, the network convergence speed will be slow, but the network error value will tend to the minimum. Therefore, learning rate is selected as small as possible, which not only makes the network training stable, but also makes the output error of the network reach the preset requirement. Its selection range is about 0.01 and 0.07. According to the actual situation of the dynamic weighing system, the initial weight range of BP neural network is set as [-1,1], and the learning rate is set as 0.01. In the network, the training steps, training errors and other parameters should be set, and the actual situation of training data should be considered for setting.

In BP neural network training, mean square error is used to measure the network effect. For all the training data, the expression of the mean square error function of BP neural network is as follows:

$$E(m) = \frac{1}{2} \sum_{k=1}^{P} E_k(m) = \frac{1}{2} \sum_{k=1}^{P} \sum_{l=1}^{L} (e_l^k(m))^2 = \frac{1}{2} \sum_{k=1}^{P} \sum_{l=1}^{L} (C_l^k - Y_l^k(m))^2 \quad (4)$$

In the above equation, C is the predicted value of the network, Y is the actual output value of the network, and P and L are the number of input and output samples respectively.

4. Algorithm Design

The system code is written by matlab. The main function is to build the neural network model and train and test it on the data set. We first initialize the network weight and neuron threshold, prepare the training data, and input the training data to the neural network. Then in forward propagation, the training data go through hidden neurons and output the data results in the output neurons. The weights and thresholds of each layer are corrected according to the error function. Until the termination condition is met. Finally, the model is verified with the test data, and the error is obtained. If the requirement is not met, the model is returned to the previous step, and the model is modified again to be trained again.

5. Data test

The system is tested on the integrity of database, interface function, user interface and system integration to ensure that the system has good performance and can withstand certain load strength and stable operation.

5.1. Data collection

During the experiment, the real static weight of the experimental animal or human body was measured in a static state, and then the animal or human body was moved on the dynamic weighing platform. The weighing platform can collect dynamic data 8 times per second (the specific collection times can be set by parameters), forming the training data of the neural network.

| Actual Weight | sensor1 | sensor 2 | sensor 3 | sensor 4 | sensor 5 |
|---------------|---------|----------|----------|----------|---------|
| 57850         | 141383  | 153153   | 28820    | 46294    | 198929  |
| 57850         | 125064  | 129928   | 64884    | 60162    | 187338  |
| 57850         | 122323  | 129483   | 82580    | 60963    | 177302  |
| ...           | ...     | ...      | ...      | ...      | ...     |
5.2. Data processing
We take the collected nearly 6,000 bars as the training data set. First, after preprocessing the train data, it is transmitted to BP neural network. After the training of the train data, the weight is updated with the back propagation algorithm, and finally the processing model of BP neural network is established.

After establishing the model, we randomly selected 4 groups of animal data and 6 groups of human data as the test data set, and compared the data results of dynamic weighing data processed by BP neural network with the real data tested under static conditions. The average error rate is 0.016kg.

| Data type | Actual weight | Data group number | Measuring weight | Average error rate | Total average error rate |
|-----------|---------------|-------------------|-----------------|-------------------|------------------------|
| Animal1   | 4.5kg         | 568               | 4.51kg          | 0.014kg           | 0.016kg                |
| Animal2   | 78.5kg        | 604               | 7.74kg          |                   |                        |
| Animal3   | 8.2kg         | 462               | 8.31kg          |                   |                        |
| Animal4   | 12.2kg        | 478               | 12.31kg         |                   |                        |
| Human1    | 58.4kg        | 600               | 59.39kg         | 0.018kg           |                        |
| Human2    | 59.1kg        | 748               | 60.16kg         |                   |                        |
| Human3    | 59.6kg        | 655               | 58.53kg         |                   |                        |
| Human4    | 60.6kg        | 489               | 61.69kg         |                   |                        |
| Human5    | 57.85kg       | 563               | 58.56kg         |                   |                        |
| Human6    | 61.25kg       | 408               | 62.41kg         |                   |                        |

6. Conclusion
This paper mainly studies how to improve the precision of the dynamic weighing system, and focuses on how to use ZigBee wireless communication, BP neural network and other technologies to process the data, to achieve the accurate acquisition of the weight data of the breeding objects in the animal husbandry farms, so as to improve the intelligent breeding management level. The average error rate obtained in this study will increase slightly with the weight of the actual object. The main reason is the influence of elastic deformation of the sensor. In the later stage, the replacement of the sensor with better stability will be considered. In addition, we will try to deepen and improve the model of neural network in order to obtain higher precision effect.

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