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The Design and Experiment of the Track-Type Equipment for Feeding Dairy Cows

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Abstract: As one of the effective ways of reducing the cost and increase the revenue, feeding dairy cows with individual precision in quantity could further develop the production potential of high-yield dairy cows and improve the milk yield of every dairy cow. Therefore, based on three kinds of technologies of radio frequency identification technology, wireless transmission technology and infrared technology and grounded on the foundation of previous studies, this thesis has completed the track-type equipment for feeding dairy cows with individual precision in quantity. The equipment takes the computer as the information management platform, adopts the singly chip microcomputer as the control platform, uses the wireless module and U disk to conduct the transmission of individual feeding data of dairy cows and guides the whole process with the track. This kind of equipment could advance automatically, identify and feed dairy cows precisely during the feeding process. This thesis also designs the matching feeding technology of the equipment, and accomplishes the test of feeding outside the cowshed, which takes “TMR + precise feeding with concentrated feed” as the feeding model, so that the feeding process could be more effective and further steady. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Dairy cows, Precise feeding, Radio frequency identification technology, Track-type, Wireless transmission, Infrared technology.

1. Introduction

Milk is grain-saving, efficient, and high correlation of the industry. It is also an important part of modern agriculture. China’s dairy herds has reached 14.4 million by the end of 2011, the national milk production reached 38.1 million tons, respectively increased 17 % and 0.8 % compared with 2008. Although China’s dairy herd and milk production has developed rapidly, the issue of low-level breeding technology and promoted production just by quantity are still exist. Data suggests that in China, cows’ average annual is 4.8 tons, compared with the developed countries in foreign dairy that average level is 8 to 9 tons, lags far behind the level of 10 tons more prominent with South Korea, the United States [1]. Therefore, how to improve cow yields and the level of China's dairy farming technology has become a serious problem. The research shows that the effective way of improvement cow yields and enhancement the level of dairy farming is implementation fine dairy farming technology. At present, the domestic researchers have carried out this study, such as Li Fade, Songzhan Hua, Gao Zhenjiang, Ni Zhijiang, etc. [2-6]. In this paper, designed the orbital individual cows fed precision equipment based on radio frequency identification, wireless transmission and infrared on the basis of Ni Zhijiang, Li Jicheng, Gao Zhenjiang, He Wei Meng, etc., which use computer for information management platform, MCU as control platform. Feeding equipment achieves data transmission for individual cows by way of a wireless device and USB. The diversity transmission improved the equipment applicability of different sizes cattle farms. Through the Human-Computer Interaction, interface more humane, the equipment enhances the operability. By the guide of orbital, the equipment realized unmanned during the feeding, and using wireless transmission module to transfer individual cows fed data simplified workflow. The design of infrared cow median centering system improved the accuracy recognition. These technologies enable the entire feeding process efficient and stable [7-10].

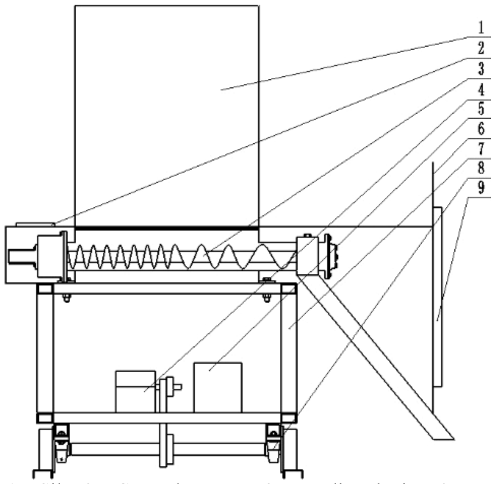
2. The Structure and Working Principle of Feeding Equipment

2.1. The Simplified Diagram of Feeding Equipment

The orbital intelligent cows feeding equipment mainly composes of mechanic system and control system. Mechanical system including feeding device and traveling device, and feeding device in which consists of feeding hopper, base, screw feeding device, stepper motors and other components; traveling device mainly consists of frame, moving motor, transmission, running gear, power , tracks and so on. Control system including identification system, data transmission system, information management system and human-computer interaction system and so on. Equipment structure diagram shown in Fig. 1.

2.2. The Working Principle of Feeding Equipment

First, the production data when the day before yesterday of cow updated to the information management system before feeding. The individual cows fed data send to the next crew by the use of a wireless device or USB mode, stored in the memory of the control system equipment. After the cattle flailed, racing system power open before start feeding, and feeding equipment travel along the track direction. During the process of moving, the infrared detection system identify cattle markers and parking the feeding equipment after identified the markers. The RFID identification system capture the individual cows' electronic ear tag identification numbers and compare it with the number that stored in the microcontroller, then the cows fed information is queried out. Then the system control stepper motor rotation through number of pulses, switch on screw feeding device, and feed the cows feeding amount that required. After feeding, feeding equipment continue to move forward into the next cow identification and feeding, the flow chart of feeding equipment showed in Fig. 2.



1 – Silo, 2 – Control systems, 3 – Feeding device, 4 – Power and Transmission, 5 – Power, 6 – Antenna Holder, 7 – Rack, 8 – Walking device, 9 – Identification system.

Fig. 1. The main diagram of feeding equipment.

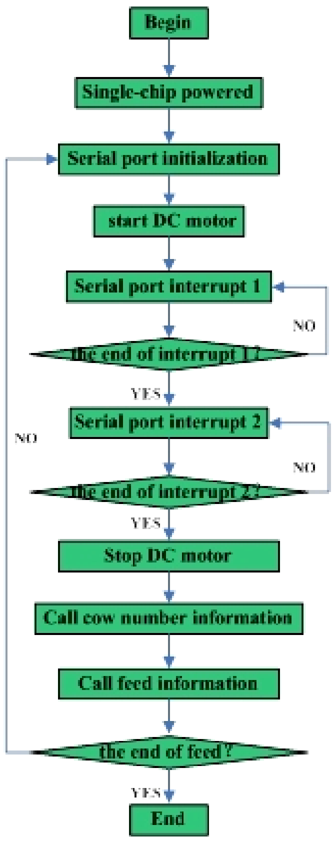


Fig. 2. Feeding flow chart.

3. Mechanical Systems

Mechanical systems including feeding device and traveling device. Feeding device mainly consists of hopper, base, and screw feeding device, stepper motor and other components. Traveling device mainly consists of frame, traveling motor, transmission, running gear, power and track and other components.

3.1. Feeding Device

Feeding device is composed by hopper, base, screw feeding device, stepper motor and so on, and its structure is shown in Fig. 3. When feeding, commands that sent by the control system to the stepper motor controller drive a stepper motor to control rotary screw auger, and fed fine amount of feed to the cows needed.

Requirements for the fed, screw feeder device used third-diameter variable pitch screw feeding apparatus [11-13]. It effectively improved the stability and reliability of feeding. Spiral auger is driven by a stepping motor and the use of servo digital stepper motor driver control the rotation speed and acceleration. MCU control procedures calculated the required ration based on fed cattle have been identified, and converted the number of pulses for the stepper motor, then the number of pulses sent to the driver to control the angular displacement, in order to achieve accurate supply of concentrate feed for dairy cattle.

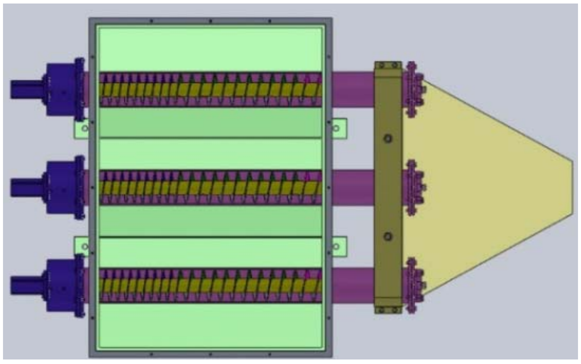


Fig. 3. Transporting device made by three sections of spiral.

3.2. Traveling Device

Traveling device mainly consisted of frame, traveling motor, transmission, running gear, power and rail and other components. The equipment used a battery as a power. Its supply voltage was 48 V. 48 V DC power source selected for the machine, also achieved the equipment parking timely and reliable through installing electromagnetic brake at the end of the DC motor. Power transmission chain drive mechanism adopted chain drive through the chain drive motor rotating the front axle. The traveling speed of equipment controlled by the speed platform adjustment knob and the speed range is 0.4-2.0 m/s.

4. Control Systems and Software Design

4.1. The Elements of Control System

Control system consisted of microcomputer control system, radio frequency identification system, data transmission device and information management system and other components.

4.2. Information Management System Programming

In this study, Vb.net is used to write the information management software which is a PC software. System realized the entry and batch import cattle-related information, achieved integrated management of cattle information. Then the system analyzes and calculates different cattle feeding information according to feeding model. Finally, the processed data transited the module of via wireless transmission or downloaded to a removable storage medium, then to the next bit machine memory. while taking the cattle farm worker, cattle production integrated information management into account, the feeding system of cows completed a precise data processing and transmission, achieved updating information storage, data query and herds warning of cattle farm, realized the effective, rapid management of cattle, improved the efficiency of information processing and cattle management simultaneously.

The main interface of information management software was shown in Fig. 4, the main function modules was system management, information management, feeding cows, statistical reports, information and early warning and etc.

Fig. 4. Interface of dairy information software.

4.2.1. System Development

System adopted the prototype to design, combined with the actual situation of cattle, based on the user needs and to conduct a comprehensive analysis of the flow of information from the perspective of the overall system, through the way of data abstraction directly and functional decomposition, organized a database, established a unified data platform. By the use of prototyping to systems development, the system was divided into a number of functional modules. The process of system design and development was shown in Fig. 5.

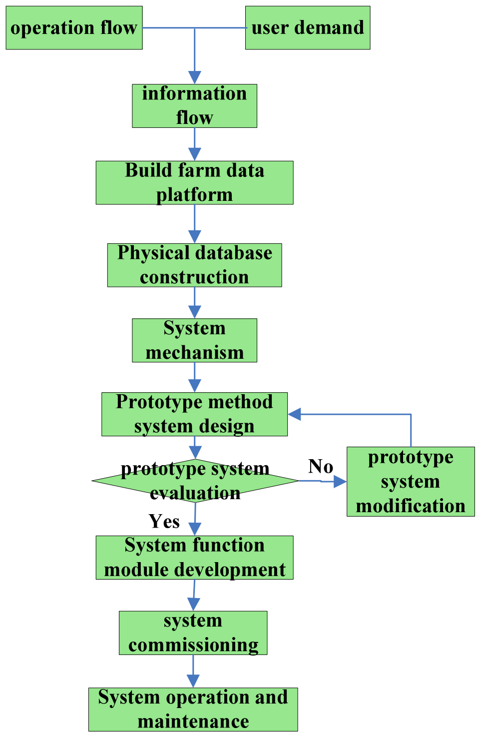


Fig. 5. Development of flow chart.

4.2.2. Database Design

The design of database table has followed the "meet user demanding" principle. Through the database system design the Access2007 database was used to build the library files Cow.mdb, and it included the following 8 documents shown in Table 1:

Table 1. Database tables.

Table name	Explanation
USERINFO	System user information
NCINFO	Introduced information about cattle
ZGINFO	Employee information
NZINFO	Information of cattle
NNGTRCNJLINFO	Milk recording of individual cow
NNRCBBINFO	Milk production nissan statement of cow
NNYCBBINFO	Milk monthly statement of cow
NNZCJLINFO	Milk expenditure records

4.2.3. Functional Achievement

Users could log into the system by account and password. The permissions be divided into system administrators, operators and ordinary users, and different roles have different rights. After entering the system, system administrators complete to manage users' information at first, registered accounts, assigned roles other than "system administrator" for new users. User accessed to the system has the rights of data storage, add, modify, and delete data.

User also have the rights of the cattle information complete, the employee information and cattle information statistics, the dairy cattle and milk production information expenses, the task of query, print, and so on. A separate set of "cows fed" module implemented the data processing, transfer and sharing between systems and equipment. Identified information of identification systems realized data validation comparison by "cows fed" module processing and carried out the amount of feed needed to fine individual cattle. By fitting the model test, feed converted to the number of pulses for the stepper motor, and then through the transmission means data is transmitted to the control system.

4.3. Communication between the Computer and Microcontroller

The computer and microcontroller exchange data in two ways: wireless transmission and U-disk transfer. The wireless communication is RFD5800 embedded multi-channel micro-power wireless data import transmission module, theoretical transmission distance up to 1000 meters, frequency is 470-510 MHz; U disk transfer directly used the PIC24F family of microcontrollers internal USB bus as controller, and read U disk data as host identity.

4.4. RFID Communication with the MCU

RFID used ID-240-type remote reader, collocation the SMC-E1334 card, use RS232 mode and interrupt realized the data exchange with microcontroller. Used CD4205 for microcontroller serial time division multiplexing, to achieve the communications between SCM and PC (or readers).

4.5. The Machine Master Program Design

The master program of Microcontroller utilized via wireless transmission or U disk transmission, and received information data of storage cows individual. When the card information is received and recognized by RDID, it called the individual cow information data to calculate the number of stepper motor pulses, then controlled the actuator operation. MCU block diagram was shown in Fig. 6.

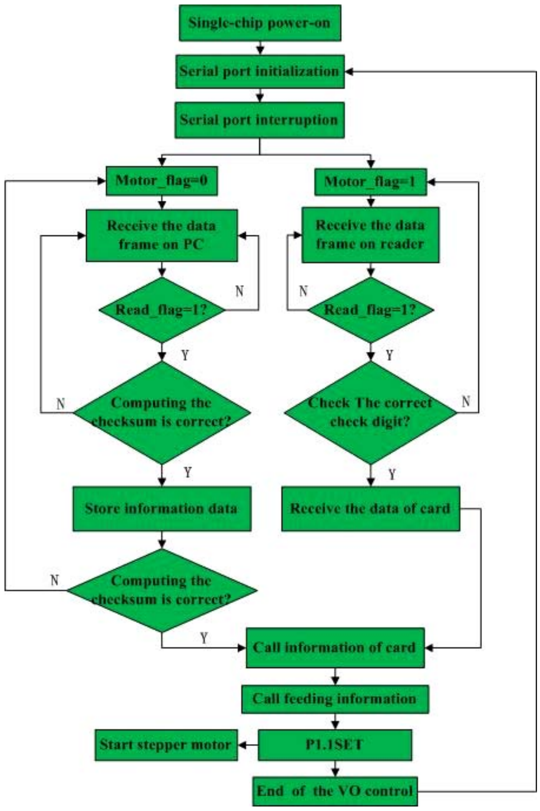


Fig. 6. Process diagram of MCU program.

5. Design the Equipment Commissioning and Feeding Process

5.1. Equipment Commissioning

After feeding tests: feeding equipment was stability when in screw speed of 60 rpm, accordingly, the screw speed adopt 60 rpm during experiment. Used least squares fitting feeding model in the speed is as follows:

$$y = 3686.504544x - 30.638918,$$

where x is the amount of feeding, kg; y is the number of pulses, piece.

The actual feeding range for equipment was 2-4 kg/bout, So set a target feeding amount was 2.0 kg/bout, 2.5 kg/bout, 3.0 kg/bout, 3.5 kg/bout, 4.0 kg/bout, each 10 times, respectively, repeated measurements, in order to carry out precision tests, the relative error of the data measurements and the target value as shown in Table 2.

Table 2. The relative error of measured and target value.

Target	The average relative error	The upper bound of error	The lower bound of error
2	-0.6 %	1.1 %	-1.4 %
2.5	-0.8 %	0	-1.6 %
3	-0.43 %	0.133 %	-1.33 %
3.5	-0.8 %	-0.4 %	-1.37 %
4	-0.43 %	0.4 %	-1.25 %

From Table 2, it means the relative error between average and target less than 2 % under different range conditions, meet the accuracy requirements of feeding.

5.2. Feeding Process Design

At present, "TMR feeding technology" has improved the efficiency of dairy farming significantly, and enhanced the level of mechanization of dairy farming, but it take the "group" as the feeding unit, couldn't take full account of the differences among individuals within populations, also could not meet the technical requirements of dairy cattle fine breeding. Therefore, this paper used "TMR + concentrate feed fed precisely" [14, 15] feeding mode during the process of cows fed. That is: first, TMR fed the basic materials needed, then based on individual body condition of the cows, feeding the cows fine individual cow feed supplement by precise equipment.

Early researches showed that too small bovine jugular flail spacing could easily lead to inter-individual cattle snatch serious, also case the equipped recognition accuracy rate decreased and other issues; too large spacing will reduce the number of cattle herds, and increase the cost of cattle. Based on the above issues, in order to ensure the feeding effect, we use self-propelled precision feeding equipment in Mission Center 121 cattle of eight divisions of Xinjiang Production and Construction Corps (XPCC) as fed mode test. The main purpose of test cattle was to investigate the effects of different spacing neck flail and travel speed on feeding efficiency, recognition rate, snatch rate, herds and other factors. The test identified two bovine jugular flail spacing was 1.2 m and 1.4 m respectively. Office for feeding outside pens, because there was no requirement on herds, which can guarantee the best feeding affection, the feeding pitch of the different index values as shown in Table 3 parameter.

Table 3. Different cow neck cangue spacing and each index.

The space of Bovine jugular flail /m	Travel speed of equipme-nt ($m \cdot s^{-1}$)	Recogn-ition rate /%	Recogni-tion accuracy/%	Snat-ch rate/%	The Response time of System response/s	Each one hundred takes time/h
1.2	0.45	100	≥96	≤4	≤2	≤0.4
1.4	0.7	100	≥99	0	≤2	≤0.35

6. Conclusion

1) Use computer as information management platform, microcontroller as control platform, wireless transmission technology for data transmission, realized precise feeding equipment design. Based on infrared technology in the field of

functional orbital cows, achieved the automatic travelling, the individual cattle fed wireless transmission and accurate information fed;

2) Experimental results showed that the best fed bovine jugular flail spacing outside feeding hall was 1.4 m, the travel speed of equipment was 0.7 m/s, in this parameter, the equipment for dairy cattle identification rate is 100 %, and recognition accuracy rate is not less than 99 %, snatch rate was 0, the system response time is less than 2 s, every one hundred cows feeding time was less than 0.35 h, Meet the precise feeding requirements.

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