Design and implementation of IoT-based beef cattle breeding system

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Abstract: Beef cattle breeding industry plays an important role in animal husbandry, however, the obsolete breeding ideas and imperfect management system make the traditional breeding mode unable to meet the growing demand of beef. In order to deal with the existing problems of beef cattle breeding industry in China, a IoT-based beef cattle breeding system that take RFID (Radio Frequency Identification) technology applied into beef cattle breeding industry was designed and implemented combined with B/S and C/S structures. The system provides the support of collecting and managing to the cowshed and cattle information, feeding information, disease treatment information, epidemic prevention information, weight information and user information. At the same time, the fixed RFID reader is used with the electronic scale to realize the accurate record of weight change during the process of beef cattle breeding. The designed IoT-based beef cattle breeding system has been applied in Lincang, Yunnan Province, China for several years. The running results showed that it is stable and reliable, and the actual needs also can be met by each function. Overall, the system is suitable for fine beef cattle breeding and can help the cattle farm realizing the digital and traceable scientific breeding method.

Keywords: beef cattle breeding system, IoT (Internet of Things), RFID

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1 Introduction

In recent years, beef cattle breeding industry is springing up in China's animal husbandry, accompanied with more and more large-scale beef cattle farms have been built and put into use, it is turning into an economic pillar industry in some places (Kang et al., 2010). However, the increased production of beef in China is still difficult to meet the consumers' demand (Liu et al., 2014), therefore, the scientific and efficient methods of beef cattle culture are urgently needed.

Nowadays, the production management model of beef cattle farms in China is still using traditional way, which is lack of complete breeding information, epidemic prevention information, disease treatment information and etc. Therefore, it is difficult to realize the accurate identification of individual beef cattle, it is difficult to weigh for each beef cattle at regular intervals, and it is difficult to reach the current international requirements for safe and high quality (Zan et al., 2006; Shi et al., 2010).

The emergence and rapid development of Internet of Things (IoT) technology provides a great convenience for human life, and it has been widely used in the smart home, medical industry, commercial and other fields (Zhang et al., 2017; Gomes et al., 2016; Guijarro et al., 2017; Lee et al., 2017; Shirehjini et al., 2016). As the core technology of IoT technology, the characteristic of light and high recognition rate makes RFID suitable for solving the problems that are difficult to identify for beef cattle in beef cattle breeding. Connecting the weighing equipment to the server through network can simplify the weighing process and provide the basis for feed in beef cattle breeding process.

IoT technology has been widely used in agriculture

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(Ge et al., 2014; Qin et al., 2014; Li et al., 2015) in recent years. Voulodimos (2010) and Lin (2016) used RFID-based mobile devices to manage animal husbandry platform. Karlsen et al. (2012) applied RFID technology into specific identification of animals in seafood supply chain. Abhijith et al. (2013) solved the redundancy problem of sensor data while using WSN technology, they also proposed a multi-level data aggregation technology to effectively monitor and control agricultural products. Balachander et al. (2013) measured and analyzed the received RSS (Received Signal Strength) and then planed and deployed the wireless sensors, they used these sensors into the management applications of precision agriculture and planting. Memon (2016) and Pingzeng (2011) realized the intelligent animal farm by monitoring the farm with various kinds of wireless sensors and IoT technology. Samad (2010), Jayaraman (2016), Wang et al. (2011) realized intelligent farm management system to save farm data records based on RFID technology, the system could regularly collect performance records and operate veterinary services to improve production and management services of farmers and management efficiency of farm. Zhou (2012) and Verdouw (2013) used RFID technology to trace and collect data, and then realized automatic identification and synchronization between devices and servers.

In view of the existing problems of beef cattle breeding industry in China, combined with the B/S structure of browser application and C/S structure of handheld equipment, an IoT-based beef cattle breeding system that applied RFID technology into beef cattle breeding industry was proposed. The proposed system could help people to construct a digital and traceable scientific breeding method.

The other main contents are as follows: The design on IoT-based beef cattle breeding system is introduced. The key equipment and methods on the system are detailed. The deployment and realization of the system are presented, and the conclusion and prospect are discussed.

2 Design on IoT-based beef cattle breeding system

The proposed system is a combination of ASP.NET MVC-based B/S architecture for browser and WinCE-based C/S architecture for handheld equipment. Through the RFID ear tag wearing in the cattle, the system realizes the management of cowshed and cattle information, feeding information, disease treatment information, epidemic prevention information, weight information and user information. The system also can manage and trace the individual information, disease and epidemic prevention information, weight change and so on of beef cattle in the whole process from breeding to sale. Through the communication with breeders and demand analysis method, we design a better database to integrate the weight data from electronic scales and the ear tag data from ear tag reader.

2.1 Overall architecture of the system

The main task of system architecture is to plan the composition of the system according to the identified requirements, and determine the organization between various parts of the system. It is the decisive factor for better realizing the whole system.

In order to realize the substantive functions of the system, the architecture is designed according to the actual requirements. In the stage of data collection, the identification of beef cattle is through RFID ear tag, the data can be input into the system on site using handheld equipment except for conventional manual input, the combination use of electronic scales and fixed RFID readers also can provide the support for gaining weight data of beef cattle. After collecting the data, they are transferred into database to store using wired network or wireless network. Users can query and manage all types of data through front pages and handheld equipment.

The system makes beef cattle breeding process much more digital and informationalized, which can promote the growth of beef cattle and realize the traceable breeding process. The overall architecture of the system is shown in Figure 1.

2.2 Design on system module

The IoT-based beef cattle breeding system can be divided into six modules, they are cowshed and beef cattle information management module, feeding information management module, disease treatment information management module, epidemic prevention information management module, weight information management module and user information management

module. The design schemes of the system modules are shown in Figure 2. The system can provide the record and management in the whole breeding progress of beef cattle, provide the informative feeding data for breeders, improve the feeding quality and provide traceable means for the feeding process. The detailed design of system modules is described as below.

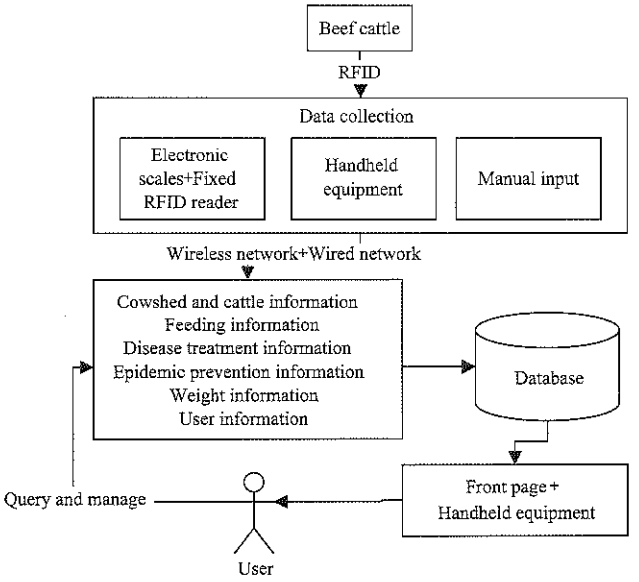


Figure 1 Overall architecture diagram of the system

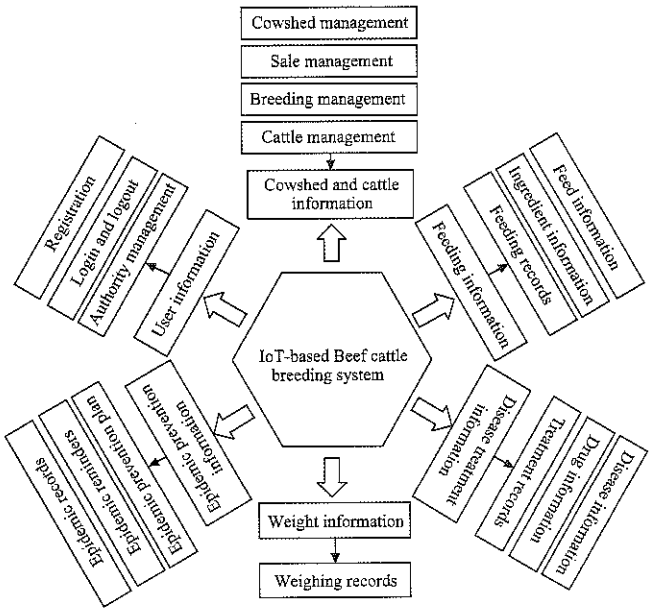


Figure 2 Design schemes of the system modules

Cowshed and beef cattle information management module: this module realizes the management of cowshed information and beef cattle information. Users can query the information through browser and manage the breeding and sale information of beef cattle by reading and writing RFID tags operated by handheld equipment.

Feeding information management module: this module realizes the management of feed information and ingredients information, including the ratios of every ingredient in various feed. Users can query the information through browser, and record the feeding information using handheld equipment.

Disease treatment information management module: this module realizes the management of common disease and common drugs of beef cattle, and records the disease treatment information. Users can query through browser based on ear tag, and record the disease treatment information using handheld equipment.

Epidemic prevention information management module: this module realizes the management of epidemic prevention plan and epidemic prevention record of beef cattle. Users can make the epidemic prevention plan through browser and record the epidemic prevention information using handheld equipment, and the system can remind the users do epidemic prevention before the plan is implemented.

Weight information management module: this module realizes the record and management of weight information. The system records the weight using electronic scales and fixed RFID reader, and users can query the weight change from browser and record the weight information using handheld equipment.

User information management module: this module realizes the management of user information, including user registration, login and other functions, and the system can provide different users interfaces and functions for different users.

Administrator can directly add or delete the data of these functions provided by system to maintain and update the database.

2.3 Design on database

The database of this system is designed according to the requirements of users, the functions and relationships between various entities in beef cattle farms are analyzed. The entities of this system are cowshed, beef cattle, breeder, weighing equipment, feed, ingredient, epidemic prevention plan, disease and drugs. Some links are existing between various entities, such as each breeder can manage multiple cowshed; each cowshed has a set of weighing equipment; each cowshed can feed a variety of

feeds, and vice versa. The E-R diagram of this system is shown in Figure 3, we can realize the corresponding data table to support the realization of the system through the design of database.

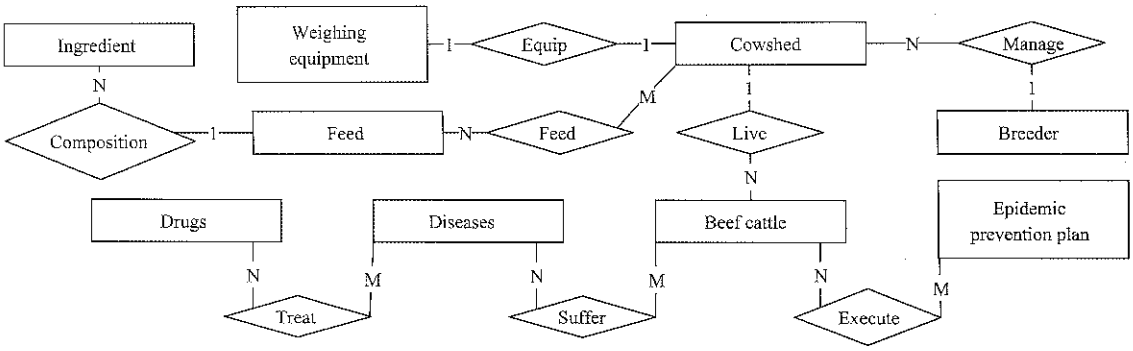


Figure 3 E-R diagram of the system

3 Key equipment and methods on the system

In this system, in addition to general B/S structure of the information management system and front browser page, some key equipment and data processing methods are also used to support the whole beef cattle breeding process.

3.1 Handheld equipment

The handheld equipment is an important part of this system, the time of data input is often after completing the work due to the single input mode of traditional IoT-based system data. In some IoT-based systems, phones are treated as the terminal equipment and data are collected based on two-dimensional code, it is often limited by the environmental brightness and other factors although the data can be collected on-site.

The handheld equipment can read RFID ear tag and it is used in our proposed system, meanwhile, the wireless network is set up in the farm and the handheld terminal is also developed, therefore, the efficiency of data collection and input on-site is much improved.

In this system, the handheld equipment is mainly used by breeders in cowshed to input the data identified from RFID ear tag. In cowshed and beef cattle information management modules, the main functions of handheld equipment are input the information of breeding and sale, modifying the information of cowshed and querying the basic information of beef cattle. In disease treatment information management module, the function is recording the diagnosis and treatment information. In epidemic prevention information management module, the main functions are querying the epidemic prevention plan and recording epidemic prevention information. In weight information management module, the function is input the weight information. The functions of handheld equipment are shown in Figure 4.

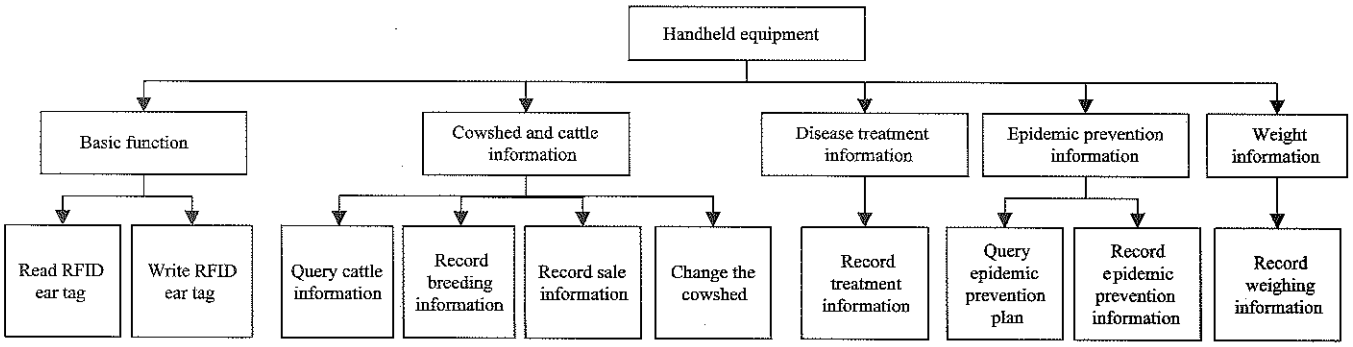


Figure 4 Functions of handheld equipment

3.2 Weighing equipment

The weight change of beef cattle is an important parameter for beef cattle feeding. It is difficult to regular weigh due to the large weight of beef cattle, especially in large beef cattle farms.

The weighing equipment in our system can solve the problem of weighing the beef cattle which was difficult. The weighing equipment is composed of electronic scale,

dash board, fixed RFID reader, antenna, scale railing and sliding door. In these components, the electronic scale is connected with dash board to display and transfer the weight information, the fixed RFID reader is connected with antenna to read and transfer the ear tag data, the scale railing and sliding door are used to secure beef cattle on electronic scale to obtain the accurate weight values. The dash board and fixed RFID reader are connected to LAN, and then, the collected data can be sent and stored in database, and the complete weight data can be obtained after processing. The connection of weighing equipment is shown in Figure 5.

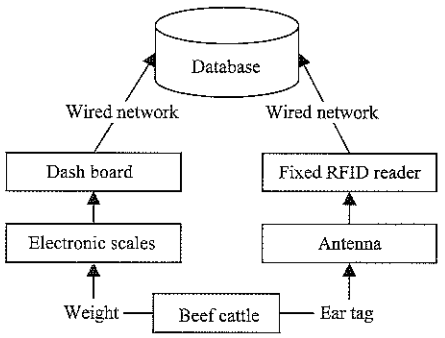


Figure 5 Connection of weighing equipment

3.3 Processing method of weighing data

As mentioned in 3.2, the dash board and fixed RFID reader are connected to LAN to transfer the weight data. The specific steps are listed as follows, the breeder can click the send button in dash board to send the weight data of beef cattle to server database after dash board value is stable. The fixed RFID reader collects the ear tag data from the electronic scale in the fixed time through antenna, and then transfers the data into database.

The separately storing of weight data and ear tag data, and the different time for transferring data into database make the time field of weight data and ear tag data not same, in this case, the weight data can't be obtained directly. Therefore, a method is needed to integrate the weight data and ear tag data to obtain the complete weighing data.

The processing of weighing data method is: to select the unprocessed weight data in time order first, the ear tag data before this data time parameter are intercepted, and then counted the occurrence number of the same ear tag, the highest reading number of ear tag and weight data is recorded as a weighing record. The pseudo code of weighing data method is shown in algorithm 1.

The complete weighing records are obtained after the alignment operation of weight data and ear tag data. It realizes the collecting of the weight information during breeding process, which is helpful for fine beef cattle breeding.

Algorithm 1 Weighing data method

Input: Data set of weight record (DWR), Data set of ear tag record (DER)

Output: Weighing record(WR)

```
for weight data (WD) in DWR do
for ear tag data (ED) in DER do
if ED.time < WD.time then
    num[ED.ed]++   // the value of num[ED.ed] is the cumulation of the same ear tag, ED.ed is the ear tag
end if
end for
WR.time←WD.time   // assign the WD.time to WR.time
WR.weight←WD.weight
WR.ed←ED.ed   // ED.ed is the key of maximal num[ED.ed]
end for
return WR
```

4 Deployment and realization of the system

4.1 The realization of browser pages

The server side of this system is completed using the framework of ASP.NET MVC, and the language of the browser is Razor, the homepage of browser is shown in Figure 6. In browser side, users can use different functions by clicking the different buttons, such as the traceability function of beef cattle, users can view the information of weight change, the situations of disease treatment and the information of epidemic prevention; Breeder can view the information of cowshed through remote connection of the system and the monitor in cowshed; Administrator can modify the information, make the epidemic prevention plan and maintain the database through the system.

The permissions of users are assigned by administrator in this system, different roles can be set to different users and the different pages can be seen for each function after login.

4.2 Realization of handheld application

The operating system of handheld side in this system

is WinCE, the applications of handheld are completed by C# under .NET FrameWork, the page of handheld side is shown in Figure 7.

Figure 7a is the homepage of handheld application, the main functions are listed in the homepage, including the reading and writing functions for the basic RFID ear tag, the management function of beef cattle information, the recording functions of disease treatment and epidemic prevention information, and the recording function of beef cattle weight.

Figure 7b is the breeding page of beef cattle for handheld equipment, breeders mark the ear tags for beef cattle breeding by the writing function of RFID ear tag. 16 bit encoding are composed in the tags, which includes 8 bit breeding time code, 2 bit cowshed code, 4 bit breeder code and 2 bit sequence code, the sequence code is sequentially accumulated in the situation that encoding is existing. After generating the code, the data of beef cattle are input into system and stored in database, and the whole breeding operation is complete.

Figure 7c is the epidemic prevention page for handheld applications. The breeders can query the epidemic prevention plan through scanning RFID ear tag, and then do epidemic prevention after determining it is needed by beef cattle. After epidemic prevention operation, the finish button of handheld equipment is clicked to record the epidemic prevention information.

Figure 7d is the weighing page for the handheld application. The breeders can manual input the weight information and scan the RFID ear tag information of beef cattle in the special situation that weighing operation can't be completed in weighing equipment.

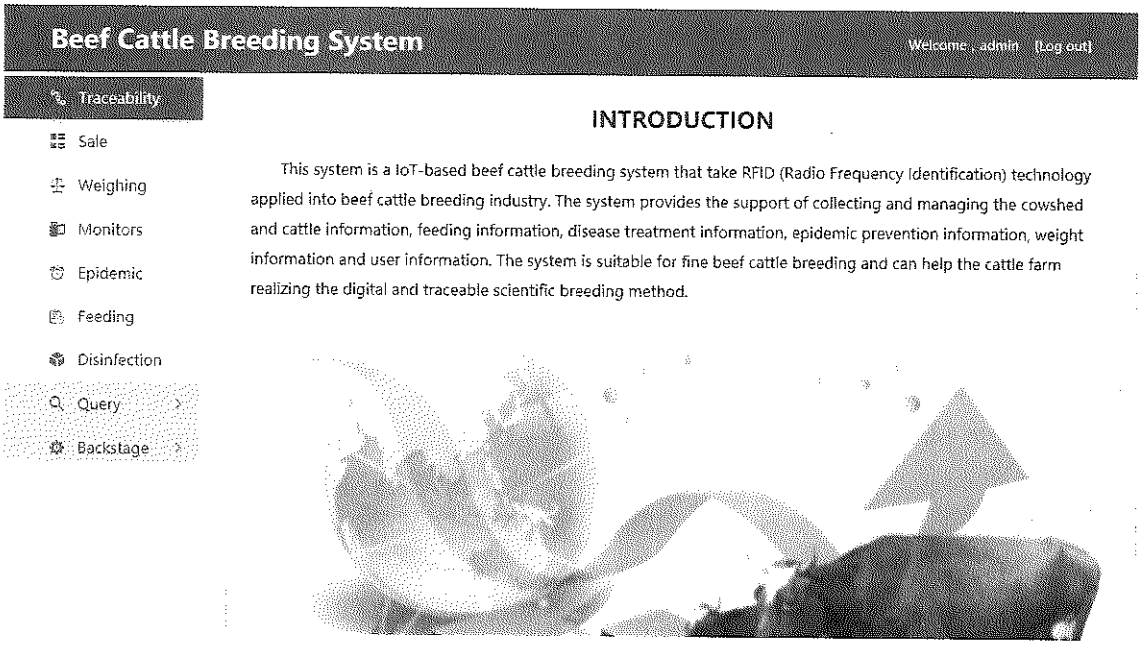
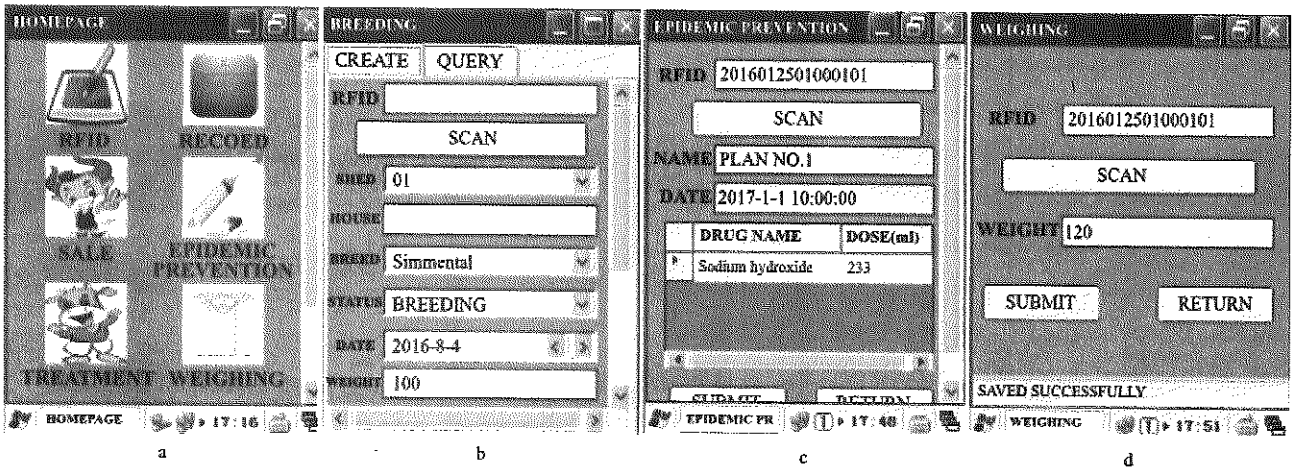


Figure 6 Homepage of browser side



a b c d

Figure 7 Exhibition of handheld page

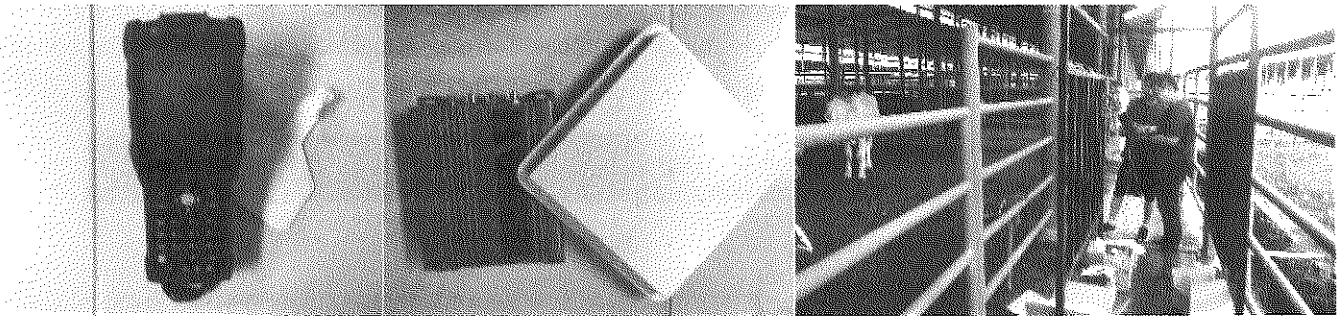
4.3 Hardware devices and deployments

The system is deployed in beef cattle breeding farm in Lincang, Yunnan Province, China. The software is deployed on Windows Server 2012, the database is Microsoft SQL Server 2012, and the Web server is Microsoft IIS7. Figure 8 shows the hardware composition and on-site deployment.

Figure 8a is the handheld equipment and RFID ear tag. The handheld equipment is equipped with RFID scanning head and can be connected to wireless network. It is also designed for anti-fall, therefore, it is suitable to use in cowshed for breeders.

Figure 8b is the fixed RFID reader and antenna. In deployment of the system, the fixed RFID reader is set up next to the electronic scale and the antenna is set up next to the scale railing of electronic scale. The RFID ear tag data of beef cattle in the electronic scale can be collected by antenna continuously when the fixed RFID reader is opening, and the data is transferred into database through fixed RFID reader.

Figure 8c is the deployment diagram of weighing equipment. The cattle channel is set in the deployment field, and the electronic scale and other hardware devices are placed into the cattle channel, therefore, it is convenient to weigh the weight after driving beef cattle to the cattle channel.



a b c

Figure 8 Hardware composition and on-site deployment

5 Conclusion and prospect

With the fast development of IoT, the using of IoT technology in beef cattle breeding can effectively reduce the labor force spent on individual records of cattle identification, improve the quality management ability, realize the safe breeding mode and help the cattle farm realizing the digital and traceable scientific breeding method. Combined with B/S and C/S structures, this paper realizes a traceable IoT-based system for beef cattle breeding based on RFID ear tag, this system can ensure the availability and realize the data input and storage of breeding farm. Besides that, we also propose a weighing equipment of beef cattle, which combines of electronic scale, dash board, fixed RFID reader and antenna, and then the data matching method is used to collect the weight data of beef cattle in breeding process. The system is deployed in the field of beef cattle breeding, Lincang, Yunnan province, China, the operation of the system is stable and the effect is perfect.

In addition, some records of the system also can be further used to effectively support breeding decisions, such as through the analysis of feeding record and weight change, the evaluation of breeding effect can be realized in breeding process. After confirming the feed amount and proportion of various ingredients in a period of time, the feeding quality can be determined according to the weight change. Meanwhile, the feeding quality can be used to provide advice on breeding, feed types and feeding volume.

Acknowledgements

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