QUARTER MILKING MANAGEMENT SYSTEM FOR DAIRY COW USING WIRELESS SENSOR TECHNOLOGIES

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Abstract

Radio Frequency Identification (RFID) technology is a short-distance sensor technology for identification and tracking objects, which was widely used in many industries such as Warehouse and Medical Managements. For transmitting the object information collecting from RFID system, Zigbee Wireless Sensor Network (WSN) provides a communication interface with PC-based system management platform based on IEEE 802.15.4 standard network protocol. The Zigbee provides a low-power, effective short-distance, and self-organizing mesh network which is suitable for the use of smaller data transmission.

Our milking management system has successfully integrated RFID and Zigbee technologies for effective recognizing the identification (ID) number of a milk cow before performing milking processes through two RFID readers deployed at sides of the entrance, receiving correct health statuses of four udders from a database built in the system management center through Zigbee network, and showing its statuses by LED-based information board at cow-side. The cow database of the management system also records the treatment information with both clinical and non-clinical mastitis. It is useful to the labor for recording mastitis statuses of udders and reducing the risk of total milk contaminated by high somatic cell counts and antibiotics during milking due to manual errors.

Keywords：*RFID , Zigbee, Dairy Farm, Quarter Milking Management, Mastitis*

1. INTRODUCTION

The major concern for dairy producer is the total milk contaminated by antibiotics during the milking process. Mastitis in agricultural industry is a common disease, and the antibiotics are mainly used to treat udder inflammation. When udder tissue is infected by the pathogen, the symptoms induced by udder tissue inflammation are generally classified into two types of mastitis: clinical mastitis and non-clinical mastitis. The appearance of clinical mastitis-infected udder can be visually recognized during milking, but non-clinical mastitis (commonly known as chronic mastitis) in appearance could not be immediately determined by inspecting [2]. These two kinds of mastitis are usually recorded by papers after finding them, but still cause the economic losses in continuous several weeks. After infecting the mastitis, the milk yields will be reduced to 5-25%, which is only a part of mastitis losses. The massive losses from the clinical mastitis include the treatment cost, high cow replacements cost and the loss milk abandoned during the treatment. Besides, with no obvious symptoms of non-clinical mastitis, it also causes lower milk yields and increases the milk somatic cell count (SCC) as well [3]. According to U.S. Census data shows that an average loss of per cow is about $180 US dollars per year, and the risk of total milk contaminated by antibiotics is incurred inevitably. Generally, the quarter milking management on the dairy cow suffered from mastitis in herd is that the colorful belts are mainly tied on the hind ankles of a dairy cow, which can recognize the front or rear quarter infected mastitis. Based on belt color, an infected quarter can be milked separately by a milking machine. However, the belts tied on the hind ankle are dirtied easily in a dirty herd environment, which leads to belt colors hard to be visually recognized and then increase the risk of total milk contaminated by antibiotics or high SCC during milking.

Hence, there are many researches to discuss the new information technologies that can solve the problem of manual recording the health information of cows. An application with RFID technology [4] is used to identify the milk cow at the entrance of traditional fishbone-type milking parlor [1] before performing the milking processes. Furthermore, the integration of RFID technology with herd management database [7-9] is available for providing real-time information through wire or wireless networks. The integrated system can provide real-time information through receiving the information from special designed RFID Tags, such as temperature, feed, and PH value. The benefits of the system deployed in dairy farm include tracing the diseases, recording cows' health and feeds, and analyzing the economic production by using the recorded information [10].

Here, we utilize two wireless sensor technologies including RFID and Zigbee WSN to develop a low cost management system of quarter milking that can provide real-time health information of udders for reducing the risk of total milk contaminated by antibiotics and high somatic cell count during milking, that is, a great potential for improving the labor efficiency and reducing considerable losses on dairy farm can be expected.

The implementation of our management system includes hardware (HW) and software (SW) platforms are described in Section 2. Section 3 and 4 introduce the detailed HW and SW implementations respectively. The experiment on a dairy farm is involved in Section 5, and the conclusion is given in Section 6.

2. MANAGEMNT SYSTEM ARCHITECTURE

Our management system integrates above two wireless sensor technologies for reducing the risk of total milk contaminated by antibiotics and high somatic cell count during milking by real time transmission and display of health statuses of milk cows before performing milking processes. Two RFID readers placed in different directions are used to ensure that at least one reader can read the tied tag on a cow, and transmit its ID number to remote management center through Zigbee WSN. The system can improve the efficiency of the milking processes and reduce considerable losses on dairy farm.

As Fig. 1 shows, the management system architecture includes PC-based database application system (DAS), RFID Reader & Tag device, data transfer board (DTB), and information display board (IDB). When a cow moves into the milking parlor, the RFID Reader 1 & 2 deployed at the entrance interrogate the Tag on the cow, and transmits the recognized ID number (or Tag number) through Zigbee WSN module on the DTB 1 & 2 deployed in cowshed to the DTB 3 deployed in the remote management center. The DAS receives the information from the DTB 3, and then performs a search of records with cows' health statuses. After finding the health information of the cow, it transmits the searching results through to the wireless network connected by DTB3 and DTB2, and the corresponding IDB will show the health statuses (especially udders' situations). For example, the health statuses of the cow with Tag 1 will shown in IDB No.1, and four LEDs on IDB will indicate the health status (mastitis-infected or not) of four corresponding udders. The LED signals can indicate three possible conditions, that is, health, clinical mastitis-infected and non-clinical mastitis-infected quarter within an udder, respectively. The farmer could easy operate the milking processes to which udder(s) without mastitis according to the indication of LEDs.

3. HARDWARE PLATFORM

The hardware platform consists of RFID Reader & Tag, Data Transfer Board, and Information Display Board. They use several design technologies including wireless sensor, wireless network, and embedded system. The following statements introduces the function of each devices designed for recognizing, transferring, and displaying the related information with milk cows.

3.1 RFID Reader & Tag

RFID operation is mainly based on transmission principle of radio waves, but the signals easily suffer from the noise interference and reflection or absorption attenuation during an RFID interrogation conducted in a warehouse or distribution center environment containing items consisting of, or packaged in, metal or liquid. The milking parlor is a metallic and moist environment, the use of a low-frequency (LF) 125 KHz (PROMAG- GP90A) RFID reader [5] can perform well in such environment. The reader has only an effective read range from 90cm to 130cm, and causes a smaller missing rate of unable to read the RFID tag tied on a cow.

Two Readers are deployed at the entrance of the milking parlor with different positions (left and right) can effective interrogate the Tag on the cow, and one or two readers can transmit the Tag number to the DAS in the remote management center. The Tag recognition processes on our management system are shown in Fig. 2, there are several situations may happen when two RFID Readers operate at the same time. The utilization of two Readers is useful to reduce the missing rate of Tag recognition processes, especially in a metallic and moist milking parlor. In general, the DAS receives two copies of Tag number from different Reader, but it may receive only one copy of Tag number due to the interference from the environment or uncertain posture of the cow resulted in a read missing of another Reader. If the DAS can receive a correct Tag number, it starts to search the database and transmit the encoded health statuses to the corresponding IDB. The worst case is that the DAS receives two different Tag numbers, but all of them are found or not found in the database. The situation major comes from the system error of RFID Readers, it needs to re-start the Readers or re-interrogate the Tag again.

3.2 Data Transfer Board (DTB)

Zigbee technology is used to perform a short-range wireless communication between RFID and PC-based management systems. The Zigbee performs IEEE 802.15.4 standard network protocol, and provides a self-organizing mesh network topology with low-power consumption. The DTB board is shown as Fig. 3. It uses a microcontroller AT89S51 to receive the RFID Tag number via a Com port, transmit the number to the DAS through stimulating the XBee (Zigbee) module [6], and transfer the received health statuses to the corresponding IDB via a RS-485 port. The transferred information on DTB is formed by RS-232 format. The Max232 chip is a dual driver/receiver that can perform the communication of RS-232 standard with TTL/CMOS signals. The microcontroller unit (MCU) on DTB1 performs a control program that executes the data transfers between RFID Reader1, and DTB3. Another microcontroller on DTB2 performs the control program that executes the data transfers between RFID Reader2, IDBs, and DTB3. The control program executed on the MCU of DTB1 or DTB2 firstly confirms the information that comes from which connection port. The information from IDB informs DTB2 to re-transmit the copy of previous statuses to the corresponding IDB due to the transmission error. The Tag number from RFID Reader will be transmitted to DTB3. The program mostly receives the encoded health statuses of milk cows, performs the decoding processes, verifies their checksum, and transmits the statuses to the corresponding IDB.

3.3 Information Display Board (IDB)

Fig. 4(a) shows the front and of IDB, and the circuit layout is placed in this face. The IDB uses an AT89S51 MCU to perform the data receiving from DTB2 via a RS-485 port, send the re-transmitting signal to DTB2 via another RS-485 port, and reset the LED signals. Fig. 4(b) shows the back of IDB, and four LEDs are used to indicate four corresponding udders of a milk cow. The positions of four udders are indicated as right front (RF), left front (LF), right rear (RR) and left rear (LR) correspond to the serial numbers of LEDs from 1 to 4. The MCU can manipulate four LEDs to indicate the health statuses of udders. Three displaying models of the LED including permanent bright, twinkling, and dark correspond to three statuses of the udder including clinical mastitis, non- clinical mastitis, and health respectively. A control program executed on the MCU of IDB firstly divides the information from DTB2 into two signals: data and control. If the IDB receives the encoded health statuses, it performs the decoding processes, verifies their checksum, and transfers the statuses to LED signals. When the IDB receives a reset signal, it resets all the LED signals to become darkness.

4. SOFTWARE PLATFORM

The software platform uses several information technologies including database, Extensible Markup Language (XML), and system management. Fig. 5 shows the data flow of the program executed on PC-based database application system (DAS). The DAS receives two information sources including Tag number and control signal. The Tag number received from DTB3 is prepared to search the record of health statuses in the database. In general, if the Tag number is correct, the corresponding record will be found. The DAS encodes the statuses, generates their checksum, and transmits the encoded statuses to DTB2. The control signals include reset and re-transmission. The management system can send the reset signal to DTB2, and reset all the IDBs while the system error is happened. A re-transmitting request that comes from IDB or DTB2 due to the receiving error will call the DAS to re-send the copy of previous data to them again.

A graphical user interface (GUI) of the DAS was developed to implement the management system as shown in Fig. 6. Milk cows with Tags that have passed through the entrance will be recorded to the upper part of the “QueueButton” GUI page by their entrance order. When a Tag number is received from RFID Reader(s), the DAS performs the search of health statuses by Tag number and shows the searching results on “Status” item. The number 1 in “Status” item indicates the right front (RF) one of udders. The number 2, 3, and 4 indicate the LF, RR, and LR one of udders. When an udder is suffered from clinical mastitis, the corresponding number will be drawn on yellow. Non-clinical mastitis and health of the udder will be indicated by red and green respectively. The records of milk cows are shown on the lower part of the GUI page. The records in database can be updated, deleted according to the current statuses of cows or reports from inspection.

5. AN EXPERIMENT OF THE MANAGEMENT SYSTEM

A dairy farm was selected for verifying our management system. There are about two hundred milk cows in this farm. We performed the system for one week, and the system worked with about 1,000 times of milking processes. When a cow moved into the milking parlor, the RFID Readers deployed at right and left sides of the entrance interrogated the Tag number tied on one ear of the cow as shown in Fig. 7 (a) and (b). The corresponding IDB showed the health statuses of the cow as shown in Fig. 7 (c) and (d). The LEDs of numbered 1 and 3 on the IDB continued permanent bright that indicated the right front and right rear one of the udders are suffered from clinical mastitis. The milking labor will not perform the milking processes for these two udders before they become healthy.

During this experiment, four errors of missing recognition were happened at the entrance by RFID Readers due to the damage of Tags. The system worked successfully after replacing these Tags. And there were no other missing recognitions happened due to the strategy of deploying two Readers. The system helped the milking labor to find the health statuses of the cows quickly and speed up the milking processes by easily seeing the health information displayed on IDB. The system also effectively reduced the risk of milk contaminated by antibiotics or high SCC during milking due to the correct information provided from DAS. The experiment showed that the management system can work successfully in the dairy farm.

From the experiment, we also found that the database in DAS can also involve the records from the environmental information, such as temperature and humidity in dairy farm. Such information can also be gathered by using current sensors found in market. The management system can easily integrate these sensors by designing a new information collection board, and transfer the information via Zigbee WSN network. These new information can help the farm manager to set up the appropriate temperature and humidity of farms through analyses and records in DAS. The health situations of cows can also be improved by adjusting these factors in the environment.

6. CONCLUSION

In this paper, a management system of quarter milking for dairy cow developed with RFID, Zgibee wireless sensor technologies, and database design is described. This system hardware consists of two RFID readers, three DTBs, and six IDBs. They can interrogate and transmit RFID tag number to PC-based database application system (DAS) for performing the database searching. This DAS includes a graphical user interface (GUI) to show the tag number, mastitis statuses of udder quarters and other recorded functions. The health statuses of milk cows can be displayed on the corresponding IDBs according to the sequence of cows in the milking parlor. With this management system presented, the manual labor to record mastitis statuses of udder quarters can be effectively assisted. Furthermore, it has a great potential to reduce the risk of total milk contaminated by high somatic cell counts and antibiotics during milking due to manual error.

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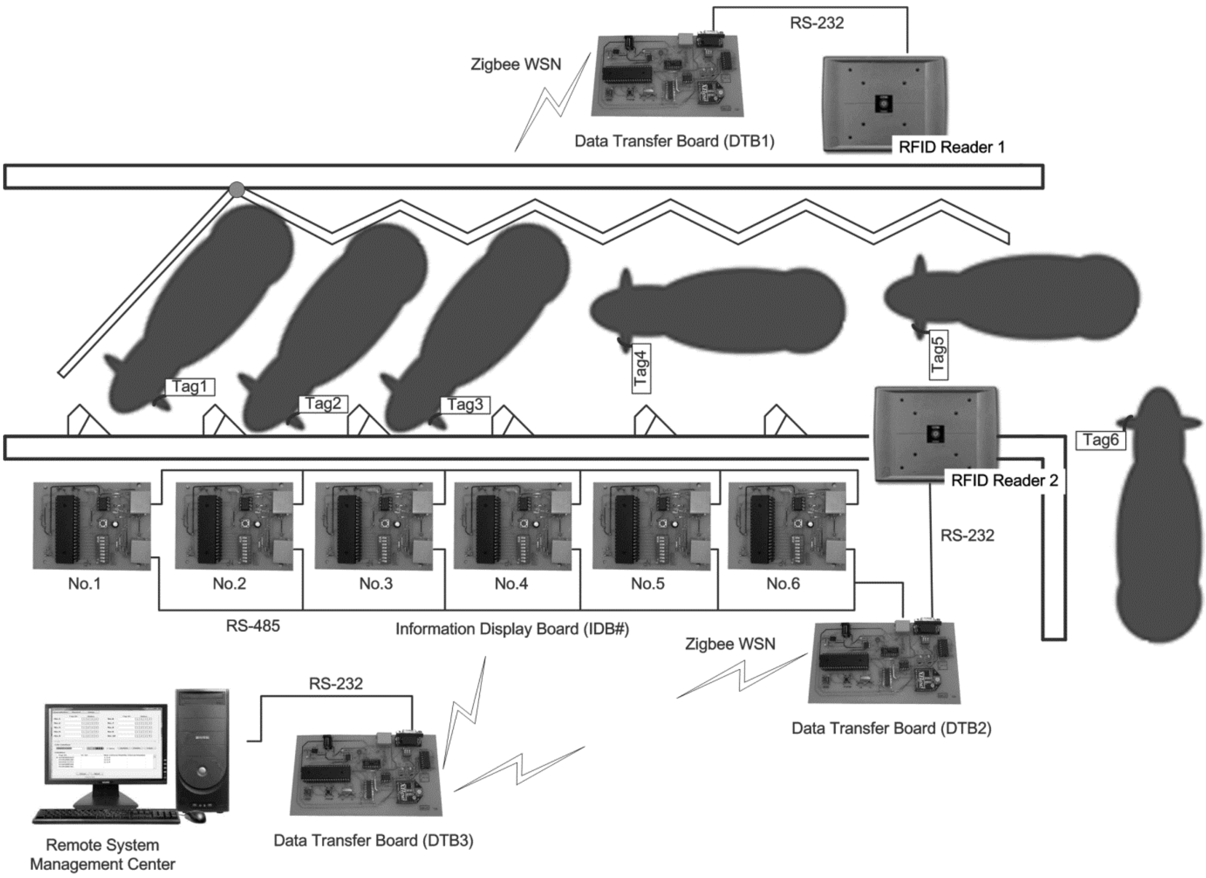

Figure 1: The management system architecture

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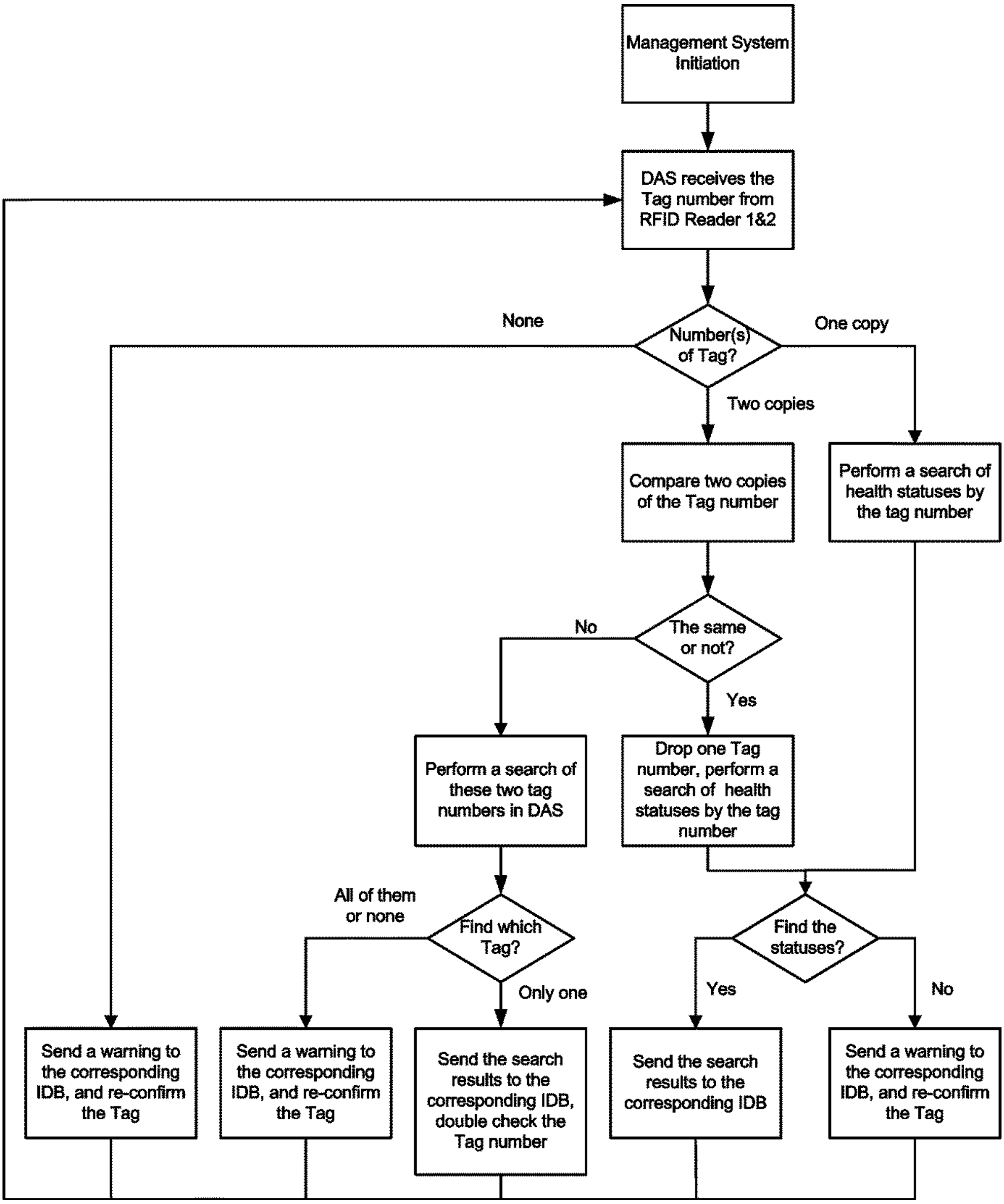

Figure 2: The data flow of the management system

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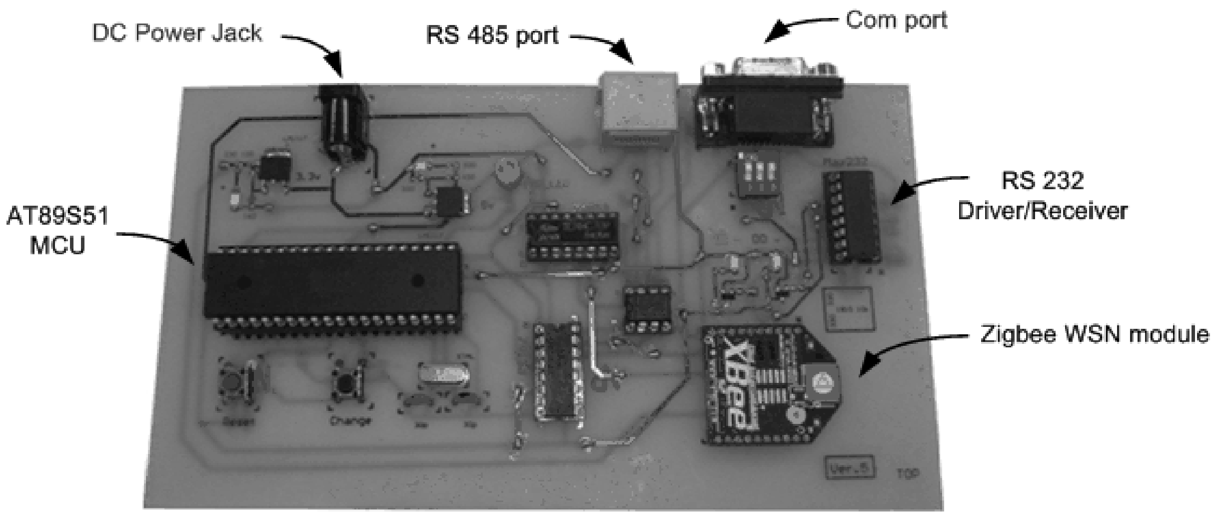

Figure 3: The control circuit of Data Transfer Board (DTB)

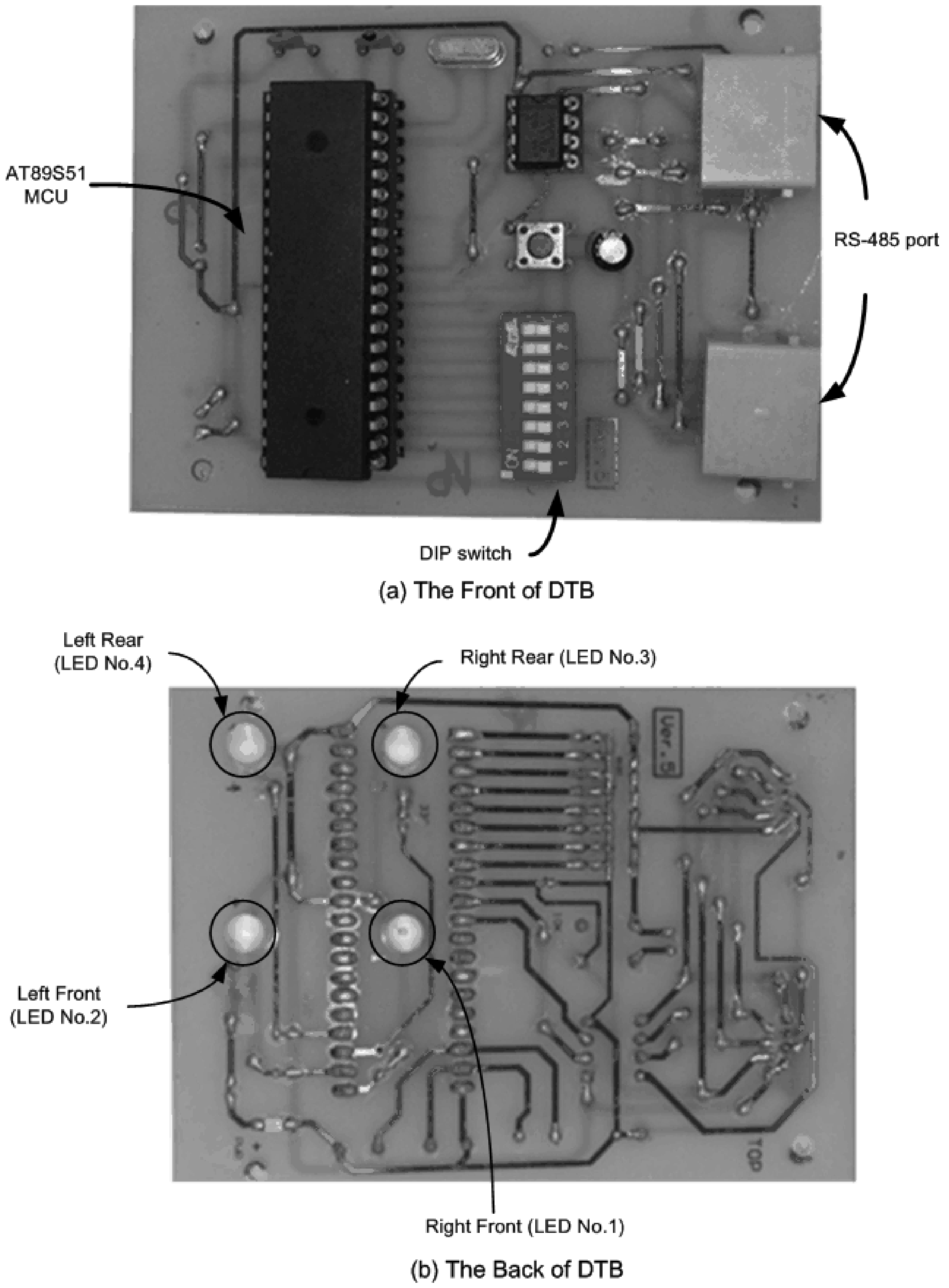

Figure 4: (a) The controller circuit of Information Display Board (IDB); (b) Four corresponding LEDs of udders in the back of IDB.

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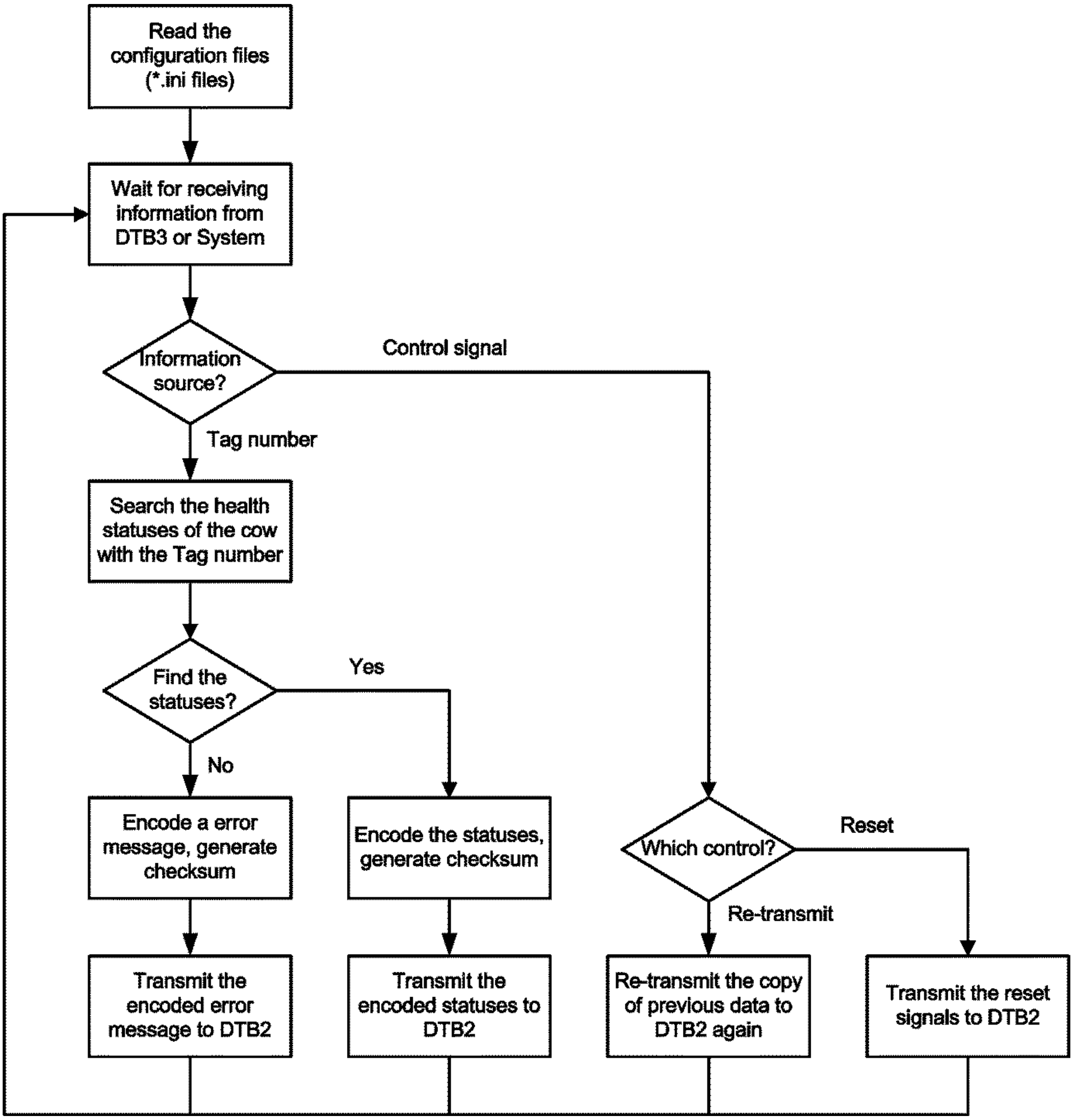

Figure 5: The data flow of the program executed on DAS

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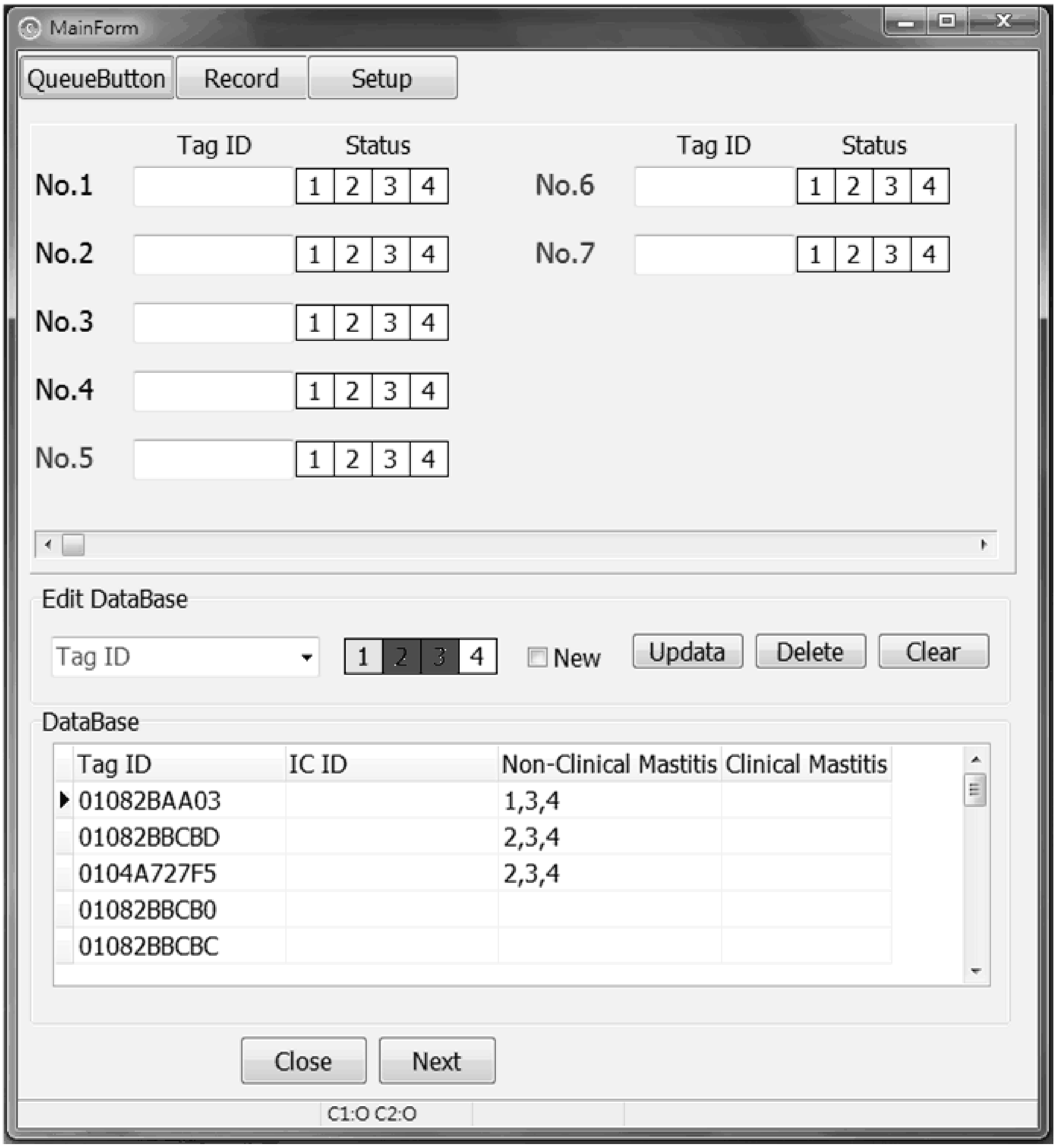

Figure 6: The graphic user interface of DAS

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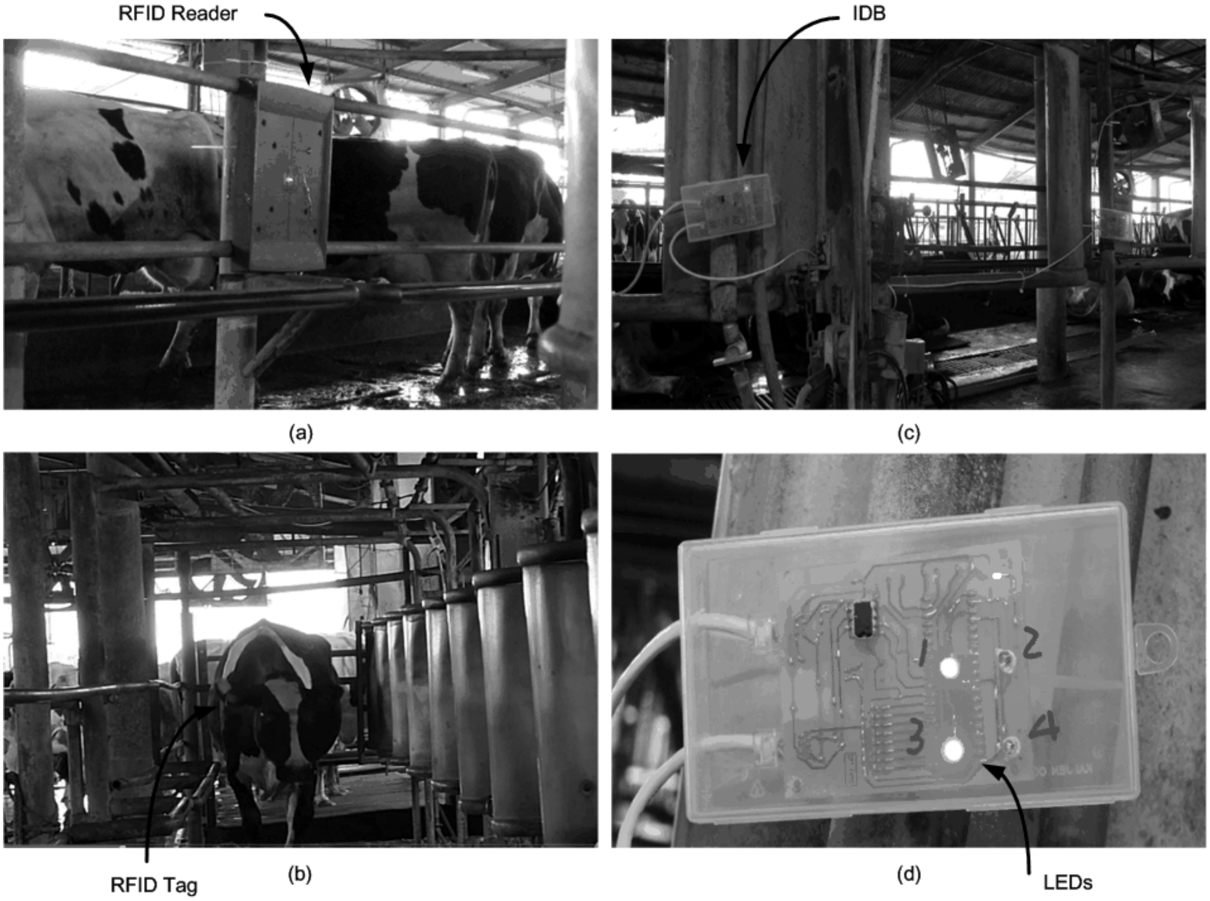

Figure 7: (a) A RFID Reader deployed at right side of the entrance in the milking parlor; (b) A cow with a Tag passes through the entrance; (c) An IDB deployed at a fixed position in the milking section; (d) An IDB shows the health statuses of the cow.