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MODEL, STRUCTURE AND ALGORITHM OF THE INTERNET OF THINGS FOR THE MANAGEMENT OF PRODUCTION QUALITY CONTROL

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Abstract. The multi-agent model for the dairy farm is constructed, described the four-layer Internet of Things (IoT) structure, algorithm on the dairy farm control is work out. Proposed the use of digital software and federated learning to solve the problem of the lack of effective data on the dairy farm and the security of data sharing.

Keywords: IoT networks, model, structure, algorithm.

Introduction

Actually, for diary form management, there are mainly two types of management involved. The first one is production management. Another is process management. In production management, milking management is the most important, this part involves the management of processing equipment, milking preservation and automatic milking, and in milk preservation, it involves the management of smart sterilization and milk cooling. In the process of management of the dairy farm, in mainly involves intelligent monitoring, dairy cow observation, feeding and reproductive management. Intelligent monitor is mainly aimed at location analysis of dairy cows' position status. The observation of the cow mainly includes the observation of the of the cow observation of the activity, behavior and physical health of the dairy cow. The feeding and reproductive management mainly involve the nutritional management and physical state management. For this two types management of dairy farm, obviously, the IoT can be an effective tool that can be applied to the management.

For this two types management of dairy farm, obviously, the IoT can be an effective tool that can be applied to the management. Some researchers have already implied IoT into this field [1–3]. Therefore, effective use of the Internet of Things technology will improve the management efficiency of the dairy farm, thereby increasing the economic efficiency and productivity of the dairy farm.

IoT Model for Dairy Farm Management

According to different types of dairy farms (different size, different numbers of cows, or different regions, urban or rural), the IoT can play a different role and solve different problems. Therefore, how to effectively use IoT technology in dairy farms is one of the current researcher issues. The first thing need to be known is the communication standards in IoT networks. At a short distance, IoT networks use such communication standards as Bluetooth, ZigBee, and less popular protocols: Thread, WirelessHART, MiWi, SNAP, and others [4]. All these communication standards use non-licensing bands of the radio frequency spectrum from the so-called ISM band (Industrial, Science, Medical), allocated for the needs of industry, medical equipment and scientific equipment. In practice, this frequency range, taking into account the restrictions adopted for it, is also used for organizing communication channels within cells and clusters of IoT cellular networks. Wi-max and LTE protocols are used for long distance. Some communication protocols used in IoT networks can be seen at table 1.

Most standards for short-range wireless communication systems sometimes called personal area network (PAN). Typically, such networks have a coverage radius of 10 to 30 meters. This kind of network can be used to connects personal electronic device of one user (phones, computers, monitors, laptops). Sometimes a short-range personal network can be optimized for certain applications called «application profiles». A Low-power Wide-area Network-energy-efficient long-range network (LPWAN) can be used for requiring long distances from monitoring objects to processing services [5]. Therefore, this kind of IoT network can be applied in a large size dairy farm to transfer the data of cows. This network uses radio frequencies in the non-licensing range (30–300 MHz), (300 MHz–3 GHz) and 800–930 MHz.

Table 1. **Communication protocols used in IoT networks**

Name of protocols	Transmission rate	Frequency band	Communication range
RFID	424 Kb/s	135 KHz	>50 cm
		13,56 MHz	>50 cm
		866–960 MHz	>3 m
		2,4 GHz	>1,5 m
NFC	424 Kb/s	2,45 GHz	<2 m
ZigBee	20/10 Kb/s–10 Mb 256 Kb/s	900 MHz/ 2,4 GHz	10 m
Bluetooth	1 Mb/s	2,4 GHz	10 m
BLE	10 Mb/s	2,4 GHz	>10 m
UWB	50 Mb/s	broadband	30 m
Wi-Fi (IEEE 802/11ac)	<6,77 Gb/s	2,4/5 GHz	100 m
Mobile networks 3G/4G (LTE)	<150 Mb/s	800/900/1800/2400 MHz	>10 km

A multi-agent approach can be created to create a model of IoT network for monitoring production quality for dairy farm management [6]. In this multi-agent structure, we will distinguish a set of agents for production quality sensors, agents for converters, agents for storing quality production indicators, agents for processing production quality indicators to obtain conclusions, agents for monitoring these indicators and conclusions. This multi-agent model is represented by the set:

$$\mathrm{IoTccm} = \{\mathrm{RAM},\ \mathrm{Ac},\ \mathrm{Amq},\ \mathrm{Apmq},\ \mathrm{Admq},\ \mathrm{Aimq},\ \mathrm{MAi}\},$$

where IoTccm – the IoT network model, RAM – a set of sensor agents (from portable analyzers of milk quality, and dairy cow health monitoring), Ac – the set of agent converters, (gateways), Amq – agents' storage of quality indicators, Apmq – agents of their processing, Admq – agents to make decisions about the quality of production, Aimq – agents interface to display indicators, MAi – monitoring agents (mobile devices to monitor production quality indices and the dairy cow). This multi-agent model can realize the information flow needed in the production management and process management of the dairy farm. Therefore, the management of dairy farms will more effective.

The structure of IoT for dairy farm management

For a comprehensive describe IoT that its architecture includes perception layer, network layer, middleware layer, application layer and business layer. But as conceptually, the IoT can belongs to the next generation of networks (NGN), so its structure is similar to the four layer of NGN, which includes smart sensors, transport environment, services and application [7].

The lowest level of the IoT structure consists of the smart objects integrated with sensors. The sensors can be used to digitize various indicators of the dairy farm, such as the location, physical condition and nutritional indicators of the dairy cow, as well as the weather, temperature, humidity of the dairy farm. The sensors digitize the physical information of the dairy farm.

The larger amount of data (temperature, location, caw's body temperature, milk quality's indicator) collected by sensors, and these data should rely on reliable and high-performance wired and wireless network infrastructure for transmission. A network layer can be constructed.

The service layer usually contains a set of information services: for example, some automate technological and business operations may will be used in IoT, supporting for operational and business activities (OSS/BSS-Operation Support System/Business Support System), some information processing method (statistical, data preprocessing, feature extraction and predictive analytics, etc.), data storage, information security, the business rule of cow dairy farm management, the business process of cow dairy farm management.

At the fourth layer named application layer, there are different types of applications in different industry, and even in an IoT system about dairy farm, for different subsystems, there are different types of application for cow dairy farm sectors.

Based on the above description, the structure of the IoT for dairy farm management can be seen in the Fig. 1.

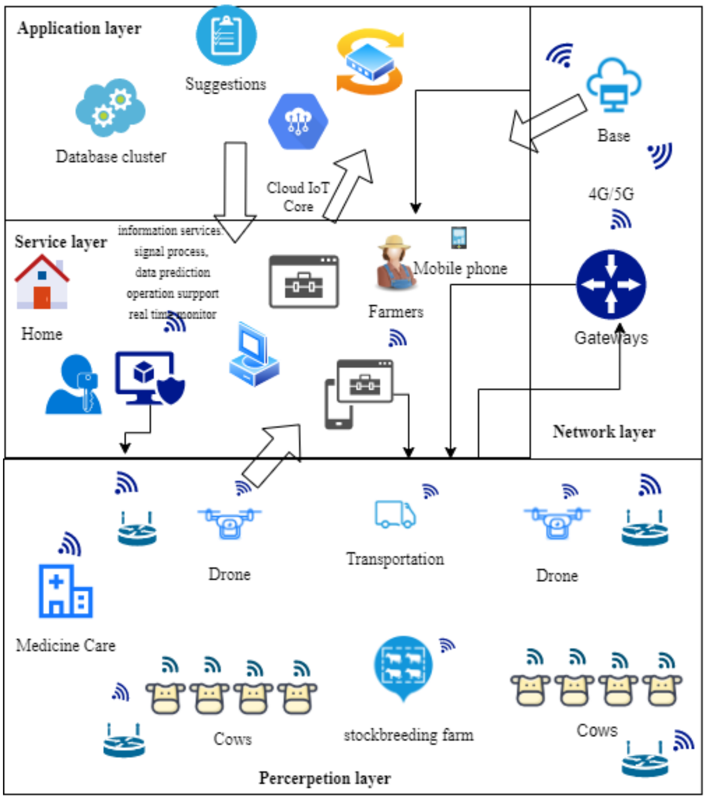

Fig. 1. The structure of the IoT for dairy farm management

Algorithms of the IoT for managing a dairy farm

It is worth noting that machine leaning (ML) algorithm usually depends on large, high-quality datasets, the data availability is poor, for reasons such as commercial competition or confidential information, some dairy farmers are generally unwilling to share relevant data, it is hard to integrate with the data sources for the ML algorithm. Digital twin (DT) [8] may a good idea to solve this problem. DT is a reliable strategy to migrate knowledge from the virtual space to physical space. This kind of DT algorithm have already implemented in crop farms [9]. A literature review of digital twin in smart farming had discussed in [10], this reference presented DT have massive scope for success in the field of sustainable agriculture, but the number of works in this field is relatively less than other domains like Manufacturing, Healthcare, Autonomous Vehicles, and Aviation, and explored the possibilities in Hydroponics.

Therefore, in response to the lack of valid data in the dairy farms, DT will be an effective technology to deal with this kind of problem.

Moreover, in response to the lack of security and privacy constraints on dairy farm data, Federated Learning (FL) [10] can be applied to dairy farm data management due to its advantages in ensuring information security during big data exchange and protection the privacy of terminal data and personal data. In work [11] discussed alternative solutions to the problem based on privacy-preserving collaborative learning, and provide a set of scenarios to show their benefits for both farmers and businesses. Therefore, FL is a suitable algorithm to tackle the lack of security and privacy constraints on dairy farm data.

Moreover, specific management issues for dairy farms, such as milk quality control, there are some indicators (lactose, fat, Chlorides, Protein) need to be detected. Table 2 is intended to describe the values of milk quality indicators for normal and mastitis.

Table 2. **The values of milk quality indicators for normal and mastitis**

Indicators	Normal milk	Mastitis milk
Lactose, %	4,7	3,9–4,5
Fat, %	3,8	2,2 (1,5–3,5)
Chlorides, %	0,091–0,1	0,147–0,15
Protein, %	3,3	<6,1

The milk quality control generalized algorithm consists of the following steps:

1. The portable analyzers for milk quality of the dairy farm are applied as sensors to collect the indicators of milk, these indicators of the milk will be transformed into sensor data.

2. Before the sensor data sent to IoT network, the device of portable analyzers need to be verified by the IoT platform (the service authorization). If the verification is not successful, then the verification request will be sent manager until the devices IDs corrected.

3. Data analyzers output the results to a gateways-converters, (instead of a computer or printer via a serial port in previous). The gateways-converters can convert and transmit the captured milk quality indicators to the cloud platform (CP). In this process, various network protocols are applied.

4. In the CP the database usually stores kinds of indicator data that received from different dairy. The database stores data received from dairy farms, taken quality characteristics by time (number, time of day, checked parameters and etc.), from different dairy farms. The knowledge base contains rules for evaluating the quality of milk.

5. Data are sent to the solver, which based on the accepted indicators and rules for processing quality indicators from the knowledge base, issues solutions for certain quality parameters. These decisions are also recorded in the database.

6. According to the different types of received data, rule handler perform action: classification data, save data into database, send data to Analytics system, send preprocessing commands and so on.

7. Mobile devices be installed an application that allows the farmer or the user to check the information that they interested from the cloud database through the site.

8. The site serves as a means of displaying obtained results on the quality of milk for manager.

Conclusion

A multi-agent model is presented for monitoring production quality for dairy farm management. Based on the multi-agent model, the four layers' structure of the Internet of Things for dairy farm management is proposed.

In response to the lack of high-quality and reliable data resources on dairy farm, a DT algorithm is proposed to applied to tackle this problem. To tackle the lack of security and privacy constraints on dairy farm data, FL as a suitable method is proposed. Moreover, for specific management issues for dairy farms, such as milk quality control, the milk quality control generalized algorithm is proposed.

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