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Digital Farming: A Survey on IoT-based Cattle Monitoring Systems and Dashboards

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Abstract

There is a steady increase in research on livestock monitoring systems that offer new ways to remotely track the health of the livestock, early predict the diseases that may affect them and intervene in the early stages to save the situation by monitoring the various vital biodata of the livestock, as well as monitoring their feeding and tracking their location to prevent any damage or rustling. In this context, this paper comes in order to highlight and discuss the most recently published articles that study the topic of cattle health monitoring and location tracking systems using advanced IoT sensors. In addition, the research provides a review of the most important software and dashboards available in the market that can be used for this purpose. The research constitutes a reference for researchers in this field and for those who wish to develop similar monitoring systems.

Keywords

Agriculture 4.0, cattle, precision livestock farming, smart agriculture, IoT, digital farming.

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Introduction

In order to check the health and the status of the cattle, the measure of the temperature and other vital biodata takes place in the barns, and it's all manually. Using these traditional methods to determine cow disease as example requires a significant amount of work. Also, cow location tracking requires a lot of effort and costs a lot. In addition, poor cow management results in the death of calves, the miss of estrus time, the loss or theft of cows, among others, and therefore a decrease in farm household income (Aleluia et al., 2022).

The livestock industry which suffers from many problems due to a decrease in livestock farms, an aging labor force, and the spread of diseases and epidemics, is looking for solutions through Internet of things (IoT) sensors and Artificial intelligence (AI) technologies. The IoT technology is used by farmers ad barn managers to monitor the livestock bio-data and analyze it with AI algorithms, thereby increasing productivity and predicting diseases by early detecting signs that even experienced people cannot detect, bringing a new era of smart livestock farming that allows remote work with fewer people (Harikrishnan and Mohini, 2021).

As IoT technology advances, it can be applied to livestock as well as actively used in smart farms that grow crops efficiently (Jabir and Falih, 2020). The goal of the livestock smart farms is to boost the quality and overcome the time and effort constraints by using the Internet and the new automated devices and sensors. It is a type of livestock farming that aims to improve the cattle wellbeing and apply intelligent and highly efficient techniques to enhance the production, and the environmental impact (Akhigbe et al., 2021).

A detailed analysis of the architecture and functionalities of the existing cattle IoT-based management systems and a discussion of its strengths and gaps, as well as an overview of the industry-available software and dashboards that can be used to manage and monitor all the aspect of the cattle are presented in this paper. It can be a useful guide for researchers planning to design and develop such an IoT-based management system, or industry specialists that want to take an in-depth look at the latest trends in this field.

This paper is organized as follows. The following section provides a comparison between traditional and modern cattle monitoring systems and describes

the recent trends of cattle monitoring. Then, in the section that follows analyzes and discuss the existing IoT-based smart cattle monitoring systems which includes health monitoring, reproduction monitoring, and location tracking systems. Then we present our own proposed smart cattle monitoring system architecture, then we highlight the existing industry-available cattle monitoring software and dashboards in use for the IoT-based cattle management, before concluding the paper.

Materials and methods

Traditional and modern cattle monitoring systems

The old breeding methods were manual and traditional, relying on the livestock manager's experience and intuition, while management work decisions are made through repeated trial and error and individual know-how. But smart farms are equipped and automated by sensors and network technology with the assistance of artificial intelligence, as is the case with plant cultivation (Jabir et al., 2021) (Figure 1). In the case of smart livestock management monitoring, automated facilities and Internet communication technology are combined to monitor the health status of the livestock or the breeding environment at any time and from any location (Na, 2019).

Before the development and expansion of the IoT technology, farmers and barn managers were using traditional methods that depend on periodic monitoring and manual diagnosis and rely either on the experience of the farmers or some software that does some calculations to determine some vital periods for the cattle or predict disease possibility.

Using the new advanced technology, remote cattle monitoring is possible, and all that the farmer need is to install the appropriate IoT sensors and use a software with a dashboard that relies on a monitoring system then it will be possible to continuously monitor all the aspects of the cattle using the IoT network. This way, the farmer can effectively manage the cattle by remotely checking all the changes that occur (Germani et al., 2019).

Recent trends in cattle monitoring

Currently, the new cattle monitoring advanced technologies are mainly used for monitoring the health, the feeding, the production and the environment, in addition to tracking the location of the cattle (Vigneswari, 2021) (Figure 2).

There are various IoT sensors available in the market that can be used for monitoring all these aspects. It can be attached to the cattle via collars equipped with network connectivity to send the biodata to a control unit that can process the data and gather it before transferring it to the cloud via a communication network, to finally make it accessible for farmers, barn managers and veterinary physicians for continuous monitoring. In this paper, we will focus both on the health monitoring and location tracking systems. Note that the health monitoring will

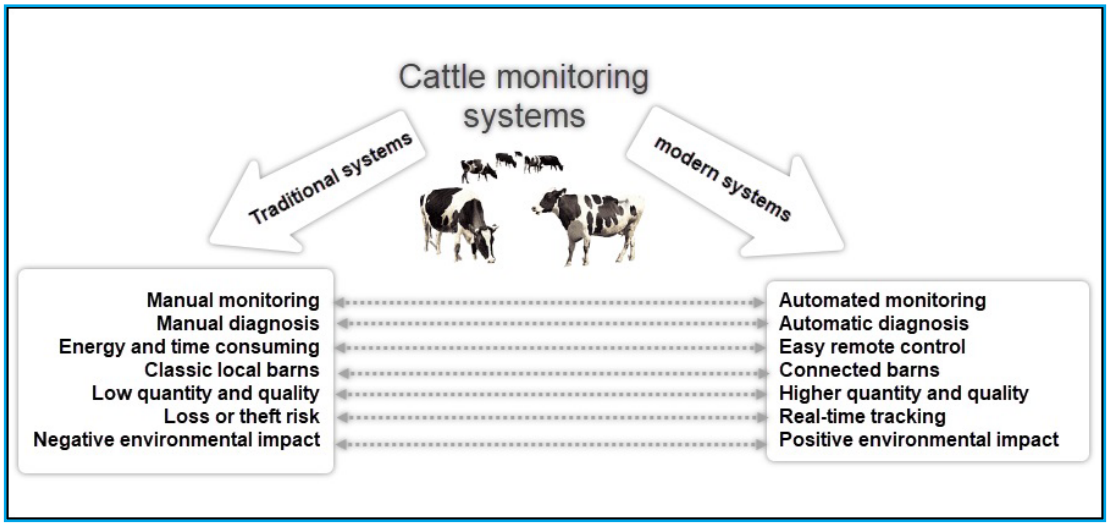

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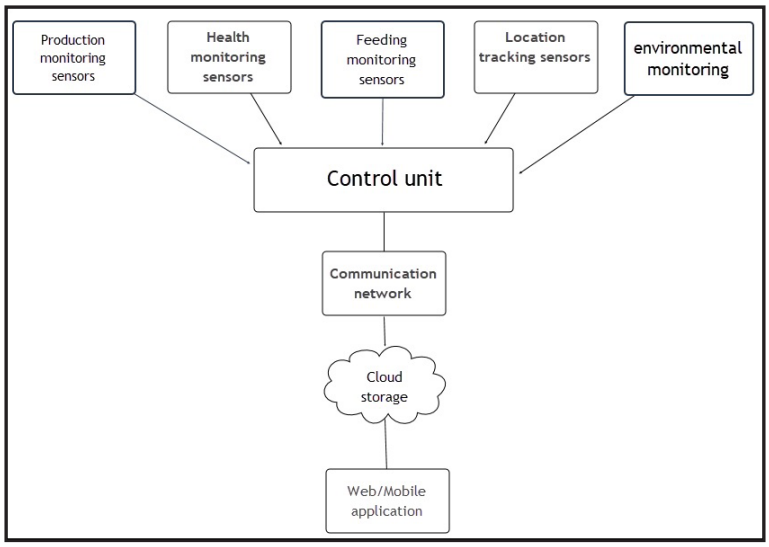
Figure 1: Comparison between traditional and modern cattle monitoring systems



Source: Author's illustration

Figure 2: The main recent trends in the smart cattle monitoring systems.

also include the reproduction monitoring. In the following section, we will discuss the latest articles on these monitoring systems that have been published in the past five years.

Results and discussion

Cattle health monitoring systems

In the article "Cloud IOT based novel livestock monitoring and identification system using UID" (Saravanan and Saraniya, 2017), the authors propose a new cloud-based Internet of Things (IoT) cattle monitoring system that can measure the cattle's physiological parameters, including its body temperature, stress level, ability to recognize gestures, and heart rate, as well as its environment, including the relative humidity and temperature of the surrounding air. These sensor-specific characteristics are saved in the cloud-based ThingSpeak-IoT analytics platform. Additionally, the monitoring system includes a web-based application created for improved communication between the cattle barn management, the owner, the farmer, and the veterinary physician.

Designing and creating an IoT-based smart cattle healthcare monitoring system prototype is the main objective of the research "Development of IoT Based Smart Animal Health Monitoring System using Raspberry Pi" (Kumari and Yadav, 2018). The created system uses a Raspberry Pi 3 with built-in Wi-Fi, a body temperature sensor, a heartbeat sensor, and a rumination sensor to monitor body temperature, heartbeat, and rumination in real time. They are transmitted over Wi-Fi using the IEEE 802.11 standard to the ThingSpeak cloud. Using the internet and an Android app on their smartphone, the farmers may access such data from anywhere. A farmer may quickly determine the health state of a cattle by carefully observing the information that is available in the ThingSpeak cloud.

In the research "Wearable Smart Health Monitoring System For Animals" (Khatate et al., 2018), they have presented a wearable health monitoring device that a cattle may wear in order to overcome and identify numerous health-related difficulties and challenges. This system is made up of modules that can measure things like body temperature, heart rate, blood pressure, and respiration rate. This system also uses IOT to send data to veterinarians or medical professionals. The suggested approach will make it easier for livestock owners to keep track of their cattle's health. This is applicable both in veterinary hospitals and at barns. As a result, farmers will no longer have to wait for veterinary specialists to evaluate and diagnose their cattle, this ultimately results in animal health decline and late treatment. So, this new method will help to solve one of the present health monitoring issues.

In the article "Designing of a Smart Collar for Dairy Cow Behavior Monitoring with Application Monitoring in Microservices and Internet of Things- Based Systems" (Pratama et al., 2019), the monitoring system provides judgments on the normal, less normal, and abnormal health of the cattle. The obtained data coming

from the IoT sensors is saved and subjected to machine learning algorithms. Depending on the gyro sensor and accelerometer's graphical output, it can be determined if the cows are feeding, lying down, or standing. The created prediction system can make the cattle health much better through rapid intervention to treat diseases in its first stage.

The suggested method in the "An IoT Solution for Cattle Health Monitoring" (Suresh and Sarath, 2019) article for automatically monitoring the health of cattle is very useful for detecting cattle illnesses. Since an alarm message can be issued to the owner if there is any deviation from the parameters' usual value, there is no longer a need for continuous monitoring. The IoT cloud platform and the mobile nodes are the main parts of the system created in this study. The data collection node is equipped with a variety of sensors to detect the health characteristics of the cattle. These data are then communicated to the mobile node using the TDMA protocol. The mobile node serves as a gateway to the IoT cloud platform where sensor data analysis is performed to identify cattle disease and alert the farm owner and the veterinarians.

Regarding the "IoT-Based Cow Health Monitoring System" (Unold et al., 2020) article, the created system precisely tracks the activity of dairy cows and identify certain physiological conditions, such as estrus, and certain health issues (e.g., mastitis). The Internet of Things (IoT) infrastructure, which consists of hardware devices, a cloud system, and end-user applications, supports this system. It can distinguish cow actions precisely thanks to new cutting-edge methods of data analysis. The proposed prototype devices were tested in a real setting and proved to be so effective and now being turned into a commercial system.

The "Analysis and Design of Cattle Management System based on IoT" (Cho, 2021) article proposes a system design for monitoring and predicting cattle illness and estrus using cattle temperature and 3-axis acceleration sensor. The whole architecture is demonstrated in order to develop the aforementioned IoT-based livestock management system. By demonstrating user demand analysis using object-oriented technique, flowchart, and screen design, an efficient analysis and design process for developing this system software is also demonstrated.

Regarding the article "Design of Scalable IoT Architecture Based on AWS for Smart Livestock" (Dineva and Atanasova, 2021), the architecture created in this study is a solution for a smart cattle monitoring system. The architecture's sensitive points were successfully tested, and the outcomes complies with the system's functional requirements. The established architecture is appropriate for future integration in animal farms, including its use for monitoring cattle status in smart farms. The purpose of this project was to develop a scalable cloud-based architecture for a smart livestock monitoring system that would include the monitoring of animal health, development, behavior, reproduction, emotional and stress levels, as well as the monitoring of the environment. The AWS services is in use and the activities they perform in relation to the suggested architecture are well described.

In the "Smart cattle health monitoring system using IoT sensors" (Suseendran and Balaganesh, 2021) paper, the autirs provide an IoT-based smart Cattle Monitoring Architecture. The health monitoring module is suggested as a way to reliably forecast cattle sickness far in advance. An antenna diversity system and Reliable Intra and Inter Gateway Routing Protocol (RIIGRP) are developed to enable reliable data transfer between the gateway and the collar attached to the cow. The suggested architecture is implemented in an Arduino sensor environment and simulated in the NS2 network simulator. In comparison to the current solutions, the suggested system achieves a 4% higher packet delivery ratio, a 14% lower latency, and 12% less energy consumption.

And finally, we have the "Design of a Cattle-Health-Monitoring System Using Microservices and IoT Device" (Shabani et al., 2020) article. In this study, they suggested and created a microservice-based architecture that may act as a bridge between IoT devices and other applications that use the data produced by this architecture. The suggested design was initially intended to be used to monitor the health of cattle, but it may be flexibly used in other fields. Machine-learning techniques were applied inside this architecture to predict cow health based on body temperature, heart rate, humidity, and location sensors to provide farmers with real-time information about the health of each animal. Based on the parameters supplied by the mobile node, it is feasible to use algorithms to calculate the current percentage value of each head of cattle's health. The architecture alerts the farmer in real time about any health issues the cattle may have. (Table 1).

Article	Parameters detected	Control unit and communication protocol	Research gaps
Cloud IOT based novel livestock monitoring and identification system using UID (Saravanan and Saraniya, 2017)	Body temperature, Heart rate, Physical gesture, Environmental parameters.	Arduino UNO, Bluetooth, Wifi.	Involves a high cost for computation and communication.
Development of IoT Based Smart Animal Health Monitoring System Using Raspberry Pi (Kumari and Yadav, 2018)	Heart rate, Body temperature, Rumination.	Raspberry Pi, Wifi.	There is no decision-making module in the system.
Wearable Smart Health Monitoring System For Animals (Khatate et al., 2018)	Temperature, Respiratory rate, Blood pressure, Heart rate.	Arduino UNO, Wifi.	Include a lot of storage and lack a decision-making module.
Designing of a Smart Collar for Dairy Cow Behavior Monitoring with Application Monitoring in Microservices and Internet of Things- Based Systems (Pratama et al., 2019)	Body temperature, Heartbeat, Movements.	Raspberry Pi, Wifi.	Lacks diagnosing cow disease and monitoring the cattle environment.
An IoT Solution for Cattle Health Monitoring (Suresh and Sarath, 2019)	Temperature, Heart rate, Humidity.	Arduino Mega 2560, Raspberry Pi, ZigBee.	There is no decision-making module in the system.
IoT-Based Cow Health Monitoring System (Unold et al., 2020)	Cow activity, Rumination, Feeding, Walking.	A Proprietary device based on nRF52832 SoC, Wifi.	Include a lot of storage and lack a decision-making module.
Analysis and Design of Cattle Management System based on IoT (Cho, 2021)	Temperature, Movements.	A proprietary device, Wifi.	ECG and heart rate are not considered.
Design of Scalable IoT Architecture Based on AWS for Smart Livestock (Dineva and Atanasova, 2021)	Temperature, Humidity, Pressure, Movements, Noise, GPS coordinates.	A proprietary device, WiFi, ZigBe, LoRaWAN, Z-Wave.	Involves a high cost for computation and communication.
Design of a Cattle-Health-Monitoring System Using Microservices and IoT Devices (Shabani et al., 2020)	Body temperature, Humidity, Heartbeat, Position of the cattle.	A propriatary device, Wifi.	Involves a high cost for computation and communication.

Source: Author's compilation

Table 1: Comparison of the various cattle health monitoring systems.

Cattle location tracking systems

The article "A Study on IoT Solutions for Preventing Cattle Rustling in African Context" (Dieng et al., 2017) comes to assess the use of existing IoT technologies for preventing cattle rustling in Africa. Theft of cattle is a serious phenomenon that presents numerous challenges to African farmers. There are currently no effective solutions for this problem. Their only chance is still the new information and communications technologies. The majority of currently used solutions rely on RFID and WSN technology. The authors of the article suggested a new tracking system prototype based on LoRa technology that would enable users to track the location and determine whether a herd is experiencing an anomalous circumstance. This prototype consists of low power LoRa end-devices and a LoRa Gateway.

The main goal of the "A Low-Cost IoT-Based System to Monitor the Location of a Whole Herd" (Maroto-Molina et al., 2019) research is to provide a low-cost method for tracking the location of an entire herd. The monitoring of 50 animals on two commercial farms that raise sheep and beef cattle has been used to assess the effectiveness of the IoT system. It has been shown that the solution based on the fusion of LPWA (Sigfox) and short-range BLE sensor networks is efficient in tracking the position of each animal in a herd at a significantly lower cost than existing systems.

"Smart Farming: An Enhanced Pursuit of Sustainable Remote Livestock Tracking and Geofencing Using IoT and GPRS" (Ilyas and Ahmad, 2020) is another study that provides an architecture of a geographical paddock suggested in this work to track the spatiotemporal behaviors of the cattle. Farmers must invest physical effort in a traditional livestock monitoring system to find the cattle that stray from frequent entry points. The suggested solution takes care of these problems by making it simple for farmers to designate a geographical safe zone for the cattle herd. When they attempt to cross the designated zone boundary, the system alerts the farmers. The technology measures each animal's distance from the safe zone's geographic limit and alerts the farmer when it approaches a certain threshold.

In the article "IOT - Livestock Monitoring and Management System" (Isaac, 2021), in order to create a system that would track the cattle and allow remote process management, the paper

specifies the top-level requirements and creates the IoT technology stack. Establishing a platform or a livestock monitoring and management system is the goal of this research. The IoT framework offers IoT solutions in a variety of fields and uses in agriculture, farming, and livestock including Cattle location tracking. The Internet of Things (IoT) is the foundation of the technological stack, and it has essential sensors to help in the monitoring process. Keeping that in mind, the data flow and exchanges are thoroughly examined in this paper.

Regarding the "Farm Animal Location Tracking System Using Arduino and GPS Module" (Ramesh et al., 2021) article, by using a sophisticated tracking system that makes use of pertinent technologies like the Global Positioning System (GPS) and the Internet of Things (IoT), this research attempts to tackle the problem of cattle locating and tracking. The system is built on a cloud computing infrastructure. The only problem is when the lead-acid battery is down. Low power components and microcontrollers must be used to prevent this problem and lengthen the battery's life.

In the "LoRaWAN based Cattle Monitoring Smart System" (Joshitha et al., 2021) study, a smart automated method for tracking the livestock is suggested. The main component of this system, LoRaWAN, helps in long-distance information transmission. A GPS module is used for location identification. Sensors that measure temperature and humidity keep an eye on the surroundings environment to better protect the animals. When compared to the current traditional ways, this sort of modern smart technology ensures greater protection and better tracking of the cattle. (Table 2).

Smart cattle monitoring system architecture

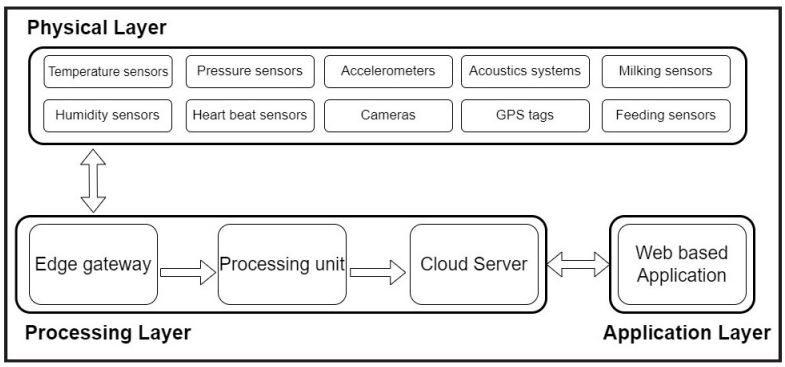
Based on the current trends and the systems proposed in previous works, for our part, we present our perception of a smart cattle monitoring system architecture that combines all the aforementioned applications that uses IoT sensors, cloud storage, and real-time data analysis into one system to continuously monitor and manage the livestock.

The smart system for monitoring cattle is structured in three layers: the physical layer, the processing layer, and the application layer (Figure 3).

Article	Technologies used	Research gaps
A Study on IoT Solutions for Preventing Cattle Rustling in African Context (Dieng et al., 2017)	LoRa, Wi-Fi, Bluetooth.	Data transmitted by LoRa has a limited payload and may face spectrum interference problems.
A Low-Cost IoT-Based System to Monitor the Location of a Whole Herd (Maroto-Molina et al., 2019)	GPS, BLE.	BLE does not support long distances or big data rates.
Smart Farming: An Enhanced Pursuit of Sustainable Remote Livestock Tracking and Geofencing Using IoT and GPRS (Ilyas and Ahmad, 2020)	GPS, GPRS.	The data rate is lower than those of competing wireless standards.
IOT - Livestock Monitoring And Management System (Isaac, 2021)	GPS, BLE.	Due to wireless transmission and reception, BLE is vulnerable to interceptions and attacks.
Farm Animal Location Tracking System Using Arduino and GPS Module (Ramesh et al., 2021)	GPS, Wifi.	Wifi has a limited range, is prone to interference and has security vulnerabilities.
LoRaWAN based Cattle Monitoring Smart System (Joshitha et al., 2021)	LoRaWAN, GSM, GPS.	LoRaWAN has a restricted network size. It's also not the best solution for real-time applications.

Source: Author's compilation

Table 2: Comparison of the various cattle location tracking systems.



Source: Author's illustration

Figure 3: The proposed smart cattle monitoring system architecture.

In the physical layer, there are IoT sensors and other devices that can be either attached to or remotely monitor the animals in the barn. These sensors include temperature, heart rate, and accelerometer sensors that monitor the vital signs of the cattle, as well as pressure, humidity sensors and cameras for the surveillance of the environmental parameters. In addition to the acoustic systems for early detection of potential cattle diseases, and milking and feeding sensors for performance tracking, along with GPS tags for following their location.

The processing layer comprises three units: the edge gateway, which collects the generated data, the processing unit, where advanced computational techniques are used for data processing, and the cloud server, which is used for data storage and database management. Lastly, the application layer consists of a web-based application that allows users to access the collected data from either a desktop or a mobile device.

Cattle monitoring dashboards

In this subsection, we will provide a list of the most well-known software and dashboards in use for cattle monitoring purposes (Table 3).

For this, we propose to take a look at both cattle monitoring dashboards that uses the traditional and modern methods.

In the following table, we have a list of software/ dashboards in use for recording the cattle data manually, i.e., using the traditional monitoring methods.

This data can be used for making predictions and keep tracking the status of the cattle. We will highlight the main functionalities for each of the existing monitoring software.

In the following Table 4, we have a list of software/ dashboards in use for monitoring the cattle's health and status using IoT sensors, i.e., using modern monitoring methods. We will highlight the main functionalities for each software.

Software	Functionalities
Cattlemax	Track animal inventories and production history and update them, maintain complete breeding and pregnancy records, record key performance measurements, manage herd health treatments, keep up with cattle purchases and sales, import and export records.
MilkingCloud	Lists, daily tasks and reports, animal profile, animals ready for insemination, list of those that need to undergo pregnancy check, animals getting close to delivery, animal addition and Animals in heat.
HerdOne	Store and track records of: inventory, accounting, reporting, reminders, pregnancy and breeding.
Livestockmanager	Livestock Manager is designed for the commercial livestock enterprises that need detailed livestock management records. It is flexible to handle multiple identifications while tracking treatments, animal movements, calving and milk production.
Livestock Management System	Disease management, vaccine management, purchase management, sales management, expense management, financial report, supplier database, client database and staff database.

Source: Author's compilation

Table 3: Existing cattle monitoring software for recording cattle data manually.

Software	Functionalities
Cowmanager	CowManager monitors the cows: estrus, health, nutrition and location based on temperature, activity, rumination, eating and resting sensors.
Smaxtec	Detection of metabolic diseases, heat detection, calving detection, monitoring of drinking behaviour, detection of heat stress, detection of subacute rumen acidosis (SARA) and detection of feeding issues.
GEA CowScout	Constant heat monitoring and display of the optimal insemination time, notifications of reduced eating and rumination times to enable early detection of health problems, and reliable animal identification in the milking parlors.
Moocall	Moocall software is based on a heat device that tells when a cow or heifer enters standing heat.
Cowlar	This software is based on smart neck collars that manage/monitors: reproduction, disease outbreaks, stress, feed optimization, milk yields, overuse of antibiotics, productivity and profits.
Halter	Halter is a New Zealand Agricultural technology startup producing GPS-enabled solar-powered collars for dairy cows. These collars connect to a smartphone app and provide: precise pasture management, seamless mob management in addition to health and heat detection.
Allflex	Health monitoring, reproduction monitoring and feeding monitoring.
IDA	Reproduction monitoring, health monitoring and analytics.
Moovement	Track cattle location and monitor cattle health.

Source: Author's compilation

Table 4: Existing cattle monitoring software based on IOT devices.

Conclusion

The aspects studied in this research present real solutions for the challenges that face farmers and barn managers every day. The new advanced Cattle monitoring systems help avoid diseases and loss of Cattle. Using these advanced systems ensures real-time monitoring of the health, production/reproduction, welfare and the environment of the cattle, which allows farmers to improve the quality and boost the profitability. In this regard, we intend to develop a new optimal cattle monitoring system based on advanced new technologies and taking into consideration the results of this study to overcome the shortcomings of the previous systems.

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