Internet of Things in Livestock Farming: Implementation and Challenges

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Abstract

The Internet of Things (IoT) has the potential to revolutionize the livestock farming industry by improving efficiency, reducing costs and increasing productivity. IoT plays an important role in providing innovative solutions to revolutionize the agriculture & farming sectors. Eminent researchers are constantly working to provide novel solutions and systems using IoT to address different challenges in the agriculture domain. The core application domains of IoT in agriculture are Livestock, Precision farming, and greenhouses that are further assembled into different domain monitoring applications, which assist the agriculturists and researchers to make better decisions. This paper explores the ways in which IoT can be implemented in livestock farming, including the use of sensor technology and automation. Additionally, the paper also discusses the challenges that must be overcome in order to fully realize the potential of IoT in the livestock farming industry. These challenges include the cost of implementation, lack of standardization in the industry, and the need for further research and development to address these issues. The paper concludes that while IoT has the potential to greatly benefit the livestock farming industry, overcoming these challenges.

1. Introduction

The Internet of Things (IoT) is a rapidly growing technology that is revolutionizing many industries, including agriculture. Livestock farming, in particular, stands to benefit greatly from the implementation of IoT technology. This work provides a summarized review of the potential applications and analysis of the current challenges and possible solutions for the Internet of Things in the agriculture and farming sectors. Further, this paper will explore the ways in which IoT can be used in livestock farming, as well as the challenges that must be overcome in order to fully realize its potential.

The world population continues to grow and now stands approximately 7 billion amidst an assumed rise in 2030 from 9.4 billion to around 10 billion in 2050 [24]. This rapid growth of population has sustained to influence the upward call for animal food and also increased influences of livestock farming systems on the biosphere during the last few decades. Moreover, the proper management of limited resources such as curtail manpower, required to reduce livestock involvement in greenhouse gases, water management, and minimize repetitive day-to-day livestock management activities are key challenges to overcome in livestock production [35]. The Internet of Things (IoT) is a most promising technique that provides various innovative solutions to modernize livestock farming. IoT technology has recently been obtaining more attention in the livestock farming sector as it can fulfill the imperative requirement for interoperability between the agriculture sector with scalability and traceability [40]. It is based on the principle of uniquely determining interconnected devices, extracting the data, and storing it in the base station, which is used by machine learning algorithms to achieve common goals. It also used location monitoring technology to notice the movement of animals and raise signals when they interrupt the boundary of the sensors of the farm and determine the health and well-being of farm animals. It is assumed that IoT technology can make a breakthrough in livestock farming systems by interconnecting sensor data of livestock and specifically who is in a remote location from the farm via the internet [38, 58].

The emerging development of IoT in livestock farming is turning the face of traditional farming by not only making it cost-effective but also making its intelligent technology that helps farmers to reduce crop wastage [36, 56]. The recent era has seen key enhancements such as automated feeding, milking through machines, and maximizing production efficiency through instrumentation, animal health monitoring, and nutrition. Despite this development, significant hurdles remain. Intensive livestock farming is essential to meet the growing demand for animal products, but due to the confined and crowded environment of livestock, housing creates it complicated for farmers to closely identify and
monitor animal health [5]. These issues lead to the intention to determine health and disease outbreaks early on, identify the disease transmission process and take preventative actions to avoid huge level economic losses [6, 7, 8]. These issues lead to growing intention in IoT-based solutions for livestock agriculture through precision livestock farming technologies [9, 57]. The upcoming section reviews the work of an eminent researcher in the field of IoT applications in livestock farming. The main aims of this work are to provide a current state of implementation in the field of IoT for livestock farming. The proposed framework provides more flexible and consistent solutions towards the automation of agriculture and farming domains. We have used three basic parameters for this study are classifiers on the Grazing, Standing and Ruminating and experimental result was compared between the results attained through AC-Collar (AC) and visual detection (VD).

This paper has been broadly divided into six sections. Section 2 provides a brief overview of eminent researchers work on IoT execution in livestock farming. Third section precisely defined the majors’ hurdles in the implementation of IoT in livestock farming. Fourth section presents the proposed work. Fifth section shows the results and experiments and finally section sixth concludes by presenting open research challenges.

The upcoming section provides an insight into the present scenario and discusses the motivation of deploying IoT in livestock farming.

2. Background

There are enormous numbers of techniques proposed to implement IoT based solutions in livestock farming. Researchers have also focused on sensor networks and artificial intelligent based farming techniques to enhance the quality and proliferation of farming and agricultural productivity. Lot of applications can be found in several livestock framing problems. Some of the important and useful contributions by different researchers have been discussed. Talavera, J.M., et al. [2] in 2017, providing a state of review in the field of IoT applications in agro-industrial and farming. The work highlights implementation details of previous systems from 2006 to 2016 with four application areas: monitoring, control, logistics, and prediction. The review study showed 62% research focuses on monitoring systems, 25% works on controls and only 13% work on logistics and prediction. In the same year, Tzounis and Katsoulas et al. [1], proposed a IoT-based model for smart agriculture and defined the key issues that IoT faces towards its propagation. In 2018 Kim Sehan [29] developed Farm as a Service (FaaS) system by using the IoT-Hub network and cloud-based technology. This system was integrated with specified agriculture devices at different levels such as register framework, connects, manages and evaluates environmental information. Critical disease beginning edge is prescribed as 20% disease occurrence and 5% infected leaf part. Later in 2019 [30], Taneja developed a SmartHerd system using a fog computing based end-to-end IoT interface that analyzes animal activities and monitors health conditions in a dairy farming set-up. The proposed system outlines a microservices-oriented interface to support the distributed computing pattern and highlights the key challenges for constructive Internet connectivity in remote farm areas. The study was processed on 147 dairy cows from the herd consisting of 150 dairy cows [30]. In the same year, F Maroto-Molina et al. [31], developed a low-cost system to enable the motorisation of an entire herd. It combines LPWA (Sigfox) and short-range (BLE) sensor networks to effectively monitor the location of individual animals in a herd through GPS collars. GPS fix-success rate was 99.88% in the sheep farm and 97.59% in the beef cattle farm. In Suresh, N. et.al [4] in 2020, developed technology that uses the sensor network, big data, and artificial intelligence to minimize manufacturing expenses, enhance efficiencies, maximize animal fortune and raise more animals per hectare. It also facilitates farmers to recover animal health; enhance revenues and lower environmental footprint. Ricardo S. Alonso R et al. in 2020 [3] designed a platform that deployed and used for testing in a real scenario on a dairy farm. It also demonstrates that the execution of Edge Computing participates in a reduction in data traffic and an enhancement in the consistency in communications among the IoT-Edge layers and the Cloud. A
precision livestock farming (PLF) framework has been defined in [6] for determining numerous farming elements such as heat by utilizing a smart sensor, which allows computerization of farm techniques and information-driven decision-making platforms. The proposed system is superlative for identifying real-time field statistics. M Zhang et.al [32] in 2021, developed W-IoT technology that was used for the development of PLF, and puts forward precise discernment of data, biocompatibility of wearable devices. This work also highlights the advantages, issues and prospects of the W-IoT in farm animals. Quy, V.K et.al. [33] in 2022 presented a IoT based demonstration for smart agriculture and enabled IoT smart agriculture ecosystems. Authors also highlight the open challenges of IoT technology in smart agriculture. Table 1 summarised the work of above defined literature and Fig. 1 highlights the major technologies.
<table>
<thead>
<tr>
<th>Enabling Technologies</th>
<th>Authors/Years</th>
<th>Methodology</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOT, Ethernet, ZigBee, Low-power WAN (LPWAN), Sensors</td>
<td>Talavera Jesus Martin (2017) [2]</td>
<td>Proposed IoT architecture implemented on four layers: application layer, service layer, communication layer and physical layer. It also reviewed academic documents from 2006 to 2016.</td>
<td>This paper highlights agro-industrial and environmental applications that use IoT applications for the agriculture sector.</td>
</tr>
<tr>
<td>IoT-Hub network and oneM2M/LoRa,</td>
<td>Kim Sehan (2018) [29]</td>
<td>IoT-Hub network model is implemented through system registers, connects, and ensures the constancy of system specialized for agricultural environments</td>
<td>The FaaS system used cloud-based technology to collect, analyze, and predict agricultural environment information on a single common platform.</td>
</tr>
<tr>
<td>End-to-End IoT platform, fog computing, radio-based communication, cloud computing</td>
<td>Taneja, M (2019), [30]</td>
<td>The fog-based system used for data classification and analysis with a four-layer model of microservice architecture.</td>
<td>SmartHerd Microservices based model addresses the challenges for connectivity and animal welfare in a smart dairy farming scenario.</td>
</tr>
<tr>
<td>IoT, GPS/Sigfox devices, LPWA and BLE sensor networks, wireless sensor network</td>
<td>Maroto-Molina F (2019), [31]</td>
<td>The system is based on the integration of two technologies through GPS collars with LPWA (Sigfox) and short-range (BLE).</td>
<td>The proposed model enables a low-cost solution to monitoring the whole herd</td>
</tr>
<tr>
<td>Sensors, Bigdata, Machine Learning, AI</td>
<td>Neethirajan Suresh (2020), [4]</td>
<td>Data collected through AI and ML algorithms to predict deviations and abnormalities. Which is used by farmers to identify, predict and prevent disease outbreaks.</td>
<td>This work highlights the issues and prospects that sensors, big data and machine learning algorithms enabled modern animal farmers to generate more animal products.</td>
</tr>
<tr>
<td>Edge-IoT, Distributed Ledger Technologies (DLT)</td>
<td>Ricardo S. Alonso R (2020) [3]</td>
<td>Used IoT, Edge Computing technique to monitor the state of dairy cattle and feed grain in a real time scenario.</td>
<td>This work explores a platform-based application of IoT, Edge Computing, and Blockchain technology for monitoring livestock and crops in a real time dairy farming. It also confirms the traceability and sustainability of the various approaches include in production.</td>
</tr>
<tr>
<td>Smart Sensors, Big data analytical, IoT Technologies</td>
<td>Astilla Jake (2020), [6]</td>
<td>IoT technologies classification for communication between farm sensors, devices and equipment. Big data analytics are used for decision information purposes.</td>
<td>The Precision livestock farming (PLF) used smart sensors &amp; IoT for automation of farm processes and data driven decision making platforms.</td>
</tr>
</tbody>
</table>
### Enabling Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Authors/Years</th>
<th>Methodology</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearable Internet of Things (W-IoT), Precision livestock farming (PLF)</td>
<td>Mengjie Zhang (2021), [32]</td>
<td>Systematic review of W-IoT technology for enabling precision livestock farming in smart farms.</td>
<td>This work discussed the benefits, issues and practical implantations of the W-IoT in farm animals.</td>
</tr>
<tr>
<td>IoT Ecosystem, Cloud</td>
<td>Quy, V.K, (2022), [33]</td>
<td>Presented Model works on three phases: first with IoT devices, secondly, communication technologies, and last phase is data process.</td>
<td>IoT based applications for improving the efficiency and eminence of agriculture.</td>
</tr>
</tbody>
</table>

### 3. Challenges

Whenever executing IoT in livestock farming, there are various issues affecting the performance of the systems used [42, 43, 44, 45, 46]. The issues determined in the literature reviewed can specify areas required to be taken into account. The majors’ hurdles in the implementation of IoT define the following.

#### 3.1 Revenue and affordability

The investment for implementing an IoT interface is quite high and much expensive for small farmers [15]. Due to the uncertainty in the market that affects selling rates of the product and gives very little margin to farmers [16]. Trust and revenue play an essential role when investing in IoT technologies and relieving the alleged risks by determining the profits from their adoption is essential. Literature [17] highlights only 25 to 30% of farmers actually utilized precision agriculture techniques on their farms. In these circumstances, it is required for IoT & technology providers to enhance the perceived value by determining the financial return from IoT in order to diminish the perceived risk of adoption many farmers have. Also required to give more robust techniques, which are worked with farmer requirements and practices in order to gain acceptance and trust of IoT technologies [51, 52, 53].

#### 3.2 Harsh Conditions

The major challenge to implement IoT in livestock farming is the harsh weather environment where sensors and other technologies are placed such as warm temperature disparity, substantial rainfall & snowfall and high humidity that cause water concentration inside devices and short circuits [18]. All devices are placed on the ground locations that experience dust, mud and corrosive chemicals that seriously harm the performance device and cause failure [19]. Alternative biochemical sensors are also exposed to soil chemical and biological implementations, which depreciate the sensors and can delude the dimensions, requiring impracticable maintenance and re-calibrations.

#### 3.3 Hardware & Software challenges

The IoT devices will have to stay active and functional reliable for long times based on the restricted power resources of batteries. Therefore, suitable software tools and low-power consumption equipment are required. Power management can be a key to several cases; however, the power consumption has still to be within the power budget of small power harvesting modules. Furthermore, the huge number of interrelated internet devices produces an incredibly huge amount of information that will soon be beyond the resource capacities of small-scale server infrastructures to handle [20, 49].

#### 3.4 Robustness and fault tolerance
There are various factors that can affect the overall robustness and fault tolerance of an IoT framework. Due to the remote location, poor mobile network connectivity and reliability is a common challenge in front of rural areas farmers. In the implantation of an IoT-based framework dealing with faults, errors and unforeseen events need to be taken into account in order to ensure the reliability of the system. Many of these issues are related to the other challenges presented here and can be handled at the device level, but also need to be thought of in the overall IoT system design [21, 54].

4. Research Methodology

This work makes its contribution by explaining the applications of IoT in livestock farming that is defined as illustrated in Fig. 2. The blueprint depicts the utilization of an IoT for smart farming and livestock management. At present, IoT is an emerging technology that provides more flexible and consistent solutions towards the automation of agriculture and farming domains. IoT-based technologies are being developed to automatically monitor, analyse and maintain livestock framing without any human involvement. The proposed framework is implemented into four phases.

**Phase 1: Deployment of Wireless Sensors:**

Nowadays, wireless sensors (WSs) are widely utilized in farming monitoring to enhance the quality and output of livestock farming. In livestock farming, sensors extract different types of information such as humidity, carbon dioxide, and heat in a real-time environment. WSs are interconnected with battery-powered sensors through wireless standards and are typically employed to assist a particular livestock application. A WSs executes various tasks such as heat-sensing, soil sensing, and moisture sensing. All these tasks are executed with a sensor that is controlled through a centralized machine and all backend operation is performed by IoT devices that are connected through the internet [50, 54, 55].

To exchange data between different IoT systems the WSs protocols have worked as the nerve center of livestock farming such as Code Division Multiple Access (CDMA), WiFi [25], LoraWan [26], and ZigBee [27] technology. ZigBee plays a key role in enabling communication over long distances when third-party services are not available like LTE, GSM, and CDMA. ZigBee technology is based on IEEE 802.15.4 standard and used to design a wireless personal area network (WPAN) for low-power radio-enabled devices. It provides energy-efficient, reliable, and cost-effective WSN applications in farming and agriculture domains. It also supports short-distance information communication among multi-tier, ad-hoc and decentralized networks. The ZigBee facilitated devices have a low- cycle, and thus, are beneficial for farming applications such as irrigation organization, insecticide, and manure control, water quality determining, where episodic data update is essential. The proposed framework was executed with a JN5139-Z01-M/02R1V device and connected through a universal asynchronous receiver-transmitter (UART) protocol to a system in which information was stored and the sensor algorithm was implemented. Three to Four JN5139-Z01-M/02R1V devices were utilized as routers. All the nodes were fixed predefined locations and were utilized as agents for the sensor algorithm and at least one of the fixed nodes required to be located within the range of the sensor's range. Table 2 described the working of different WSN/IoT embedded platforms.
### Table 2
**WSN/IoT embedded platforms**

<table>
<thead>
<tr>
<th>Platform name</th>
<th>Microcontroller</th>
<th>Microcontroller</th>
<th>The program, Data Memory</th>
<th>Flash, EEPROM, Ext. Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iris Mote</td>
<td>ATmega 1281</td>
<td>Atmel AT86RF230</td>
<td>8 KB RAM</td>
<td>128 KB, NesC, C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>802.15.4/ZigBee compliant radio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TelosB/T-Mote Sky</td>
<td>Texas Instruments MSP430 microcontroller</td>
<td>250 kbit/s 2.4 GHz IEEE 802.15.4 Chipcon Wireless Transceiver</td>
<td>8 KB RAM</td>
<td>48 KB, NesC, C</td>
</tr>
<tr>
<td>Zolertia Remote</td>
<td>CC2538 ARM Cortex-M3</td>
<td>Dual Radio: 802.15.4/CC1200 868/915 MHz</td>
<td>32 KB RAM</td>
<td>512 KB, C, NesC</td>
</tr>
<tr>
<td>Arduino Yun (2 processors)</td>
<td>ATmega32U4/Atheros AR9331</td>
<td>Ethernet, Wifi</td>
<td>2.5 KB, 64 MB DDR2</td>
<td>1 KB/16 MB, C, Processing, Linux</td>
</tr>
<tr>
<td>Intel Galileo/Edison</td>
<td>Intel Quark X1000/Intel Atom</td>
<td>External modules/Wifi/Bluetooth LE</td>
<td>256 MB RAM/1 GB RAM</td>
<td>8 MB, SD card/4 GB, SD card, C, Processing/Linux</td>
</tr>
</tbody>
</table>

### Phase 2: Monitoring System: Sensors and Machine Learning

This phase focuses on continuously monitoring animal physiological conditions through Sensors and machine learning techniques that are enablers to maximize the animal physical condition and optimize farm productivity. All animals carried sensors generating time accelerometer information placed on a collar on the neck at the back of the head. It used to identify how sensor data from different placement can classify a range of typical animal movements & behaviours. It monitors cattle for 24 hr per day and extracts animal behaviours, predominantly 'restlessness', for improving the herd fertility.

Figure 3 highlights the sensor coordinators of animal monitoring devices that are implemented with the ZigBee standards. It is developed to detect animal physiological gestures such as sitting, standing, eating, heartbeat, body temperature, and environmental elements such as humidity and air temperature. The adjacent temperature and humidity offer the exact calculation of the Temperature Humidity Index (THI). The result of the executed sensor module is sent to a processing module for decision-making processing with sensed signal and analog output of the sensor node is fed to an integral ADC of the microcontroller in the processing module. The result data of the proposed framework is sent to the base terminal through the wireless communication interface and based on output data, the next task will be performed through the IoT device.

The proposed framework excels at extracting, processing, and evaluating huge amounts of data and used it for making effective decisions. The following steps used to monitor the parameters:
Step 1: Pre-processing

Step 2: Date & Feature Extraction

Step 3: Classification & data analysis

Step 4: Features determination from time representation of the signal

\[
\text{Mean } \mu_T = \frac{1}{n} \sum_{i=1}^{n} X_i \\
\text{Standard Deviation } \sigma_T = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (X_i - \mu_T)^2}
\]

Step 5: Monitoring Results

It also helps farmers to track animal behaviors in real-time with advanced machine learning (ML) algorithms and make precise decisions and execute timely disease interventions. It is very typical for farmers to find changes in feeding habits, liquid intake, and infrequent body movements of a sick animal amid a huge herd of animals. In these situations, sensors, machine learning algorithms, and IoT play an important role in helping farmers such as anomalous behaviors, thereby promptly predicting and preventing disease outbreaks.

**Phase 3: Automatic Disease Detection**

In livestock farming animals can get several viruses due to variant conditions and checking all animals on a daily basis is an impossible and time-consuming task. It is a lengthy process to manually and individually check the health condition of animals. Therefore, to find an automotive way of monitoring animals' health, we work on automatic disease detection. For an animal suffering from a disease, the sensors detect modified changes in the animal body to make it easy for a farmer to find and treat the diseases promptly. A mounted sensor can extract the behavior of an animal and maintain data of it. These kinks of data assist us in taking up the next decisions.

The proposed module works on four steps of development of a particular collar device and sensor technique for disease detection:

**Step 1:** Automatically determines the animal behavioral or physiological parameters and visualization it.

**Step 2:** Data interpretation phase used to detect and connect with animal behaviour or physiology and establish link to animals health status.

**Step 3:** Information integration phase used to integrate multiple information resources to directly find the direct animal health condition that need attention.

**Step 4:** Final phase decision support system works that aids to make a decision e.g., whether animal is healthy or not.

Table 3 highlights the different types of wearable wireless sensor devices that have been used for detecting environmental parameters. For example, the farmer can evaluate any disease with the assistance of accelerometers extracting animal activities that can be retrieved such as load sensors, temperature sensors, heartbeat sensors, and microphones. It helps to measure the animal's daily life behavior such as disease symptoms, temperature change, mooing, body weight changes, and pulse rate change.
Table 3
Commercially available Wearable Wireless Sensors

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Company</th>
<th>Sensor Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cowheat</td>
<td>Incall</td>
<td>Accel, Temp, Humid</td>
</tr>
<tr>
<td>CowScout</td>
<td>GEA</td>
<td>Accel</td>
</tr>
<tr>
<td>Dr. Cowbell</td>
<td>Innovit</td>
<td>Accel</td>
</tr>
<tr>
<td>Farm note color</td>
<td>Farm note</td>
<td>Accel</td>
</tr>
<tr>
<td>headphones</td>
<td>Media</td>
<td>Accel</td>
</tr>
<tr>
<td>HR Tag</td>
<td>SCR</td>
<td>Accel, Sound</td>
</tr>
<tr>
<td>Ida</td>
<td>Connecterra</td>
<td>Unknown</td>
</tr>
<tr>
<td>MooMonitor+</td>
<td>Dairymaster</td>
<td>Accel</td>
</tr>
<tr>
<td>Silent Herdsman</td>
<td>Afimilk</td>
<td>Accel</td>
</tr>
<tr>
<td>U-Motion</td>
<td>Desamis</td>
<td>Accel, Atm press</td>
</tr>
<tr>
<td>walk</td>
<td>Ricoh</td>
<td>Accel</td>
</tr>
<tr>
<td>AfiAct II</td>
<td>Afimilk</td>
<td>Accel</td>
</tr>
<tr>
<td>Crysta Act+</td>
<td>Fullwood</td>
<td>Pedom</td>
</tr>
<tr>
<td>IceCube</td>
<td>USRobotics</td>
<td>Accel</td>
</tr>
<tr>
<td>Overt</td>
<td>CRV</td>
<td>Pedom</td>
</tr>
</tbody>
</table>

Phase 4: Automatic watering system

Dairy farming worldwide faces a lot of challenges around animal welfare, food safety, farm profitability, and work efficiency is a varying time-consuming process. The productivity of milk is depending on various aspects such as food quality, water, temperature, and humidity conditions. It is required for the profitability of the animals to provide sufficient water and quality feed. Because these essential requirements closely work with milk production. The proposed system facilitates the maximum water supply during the highest feeding phase. The proposed framework is standard and most practical in real-time livestock farming. It consists of an insulated floor and a heated bowl that automatically works with water from a pressure line. A machine learning algorithm regulates the water ratio in the bowl. The next section explores the results and experiments.

5. Results And Experiments

The results proposed a system calculated on the basis of trial data collected for execution purposes. Accelerometer sensors were placed in the collar (AC-Collar) of animals. IoT devices used to measure the animal’s behaviours and conditions. Sensor data retrieved from the accelerometer were used in this testing. The squared acceleration magnitude (acc<sub>m</sub>) was measured as:

\[ acc_m = \sqrt{acc_x^2 + acc_y^2 + acc_z^2} \]
where \( \text{acc}_x, \text{acc}_y, \text{acc}_z \) are the three axes of the accelerometer. The \( \text{acc}_m \) measure is used to calculate the desired features and utilized squared acceleration magnitude and extract features from that measure. In this proposed work, we have used six behaviour parameters that determined the animal behaviour in particular conditions: Grazing, Resting, Walking, and Standing, Ruminating and Other. We have used three basic parameters for this study are classifiers on the Grazing, Standing and Ruminating. The \( \text{acc}_m \) measure was implemented on 20 samples and statistical features were retrieved through the IoT devices. Samples were retrieved 20 samples apart along the time measure. 35 statistical features were determined from each time measure. The determined features were applied to train the Random Forest Classifier that formed better classification consequences for our dataset. The random forest classifier applied in the proposed framework for using randomly selected features. Bagging is used to enable a training data set by casually drawing with replacement J series, where J is the size of the original training set that is further used for every feature combination. For a given training set \( S \), selecting one case at random that it relates to particular class \( L_n \), the index can be written as:

\[
\sum \sum_{m \neq n} \left( \frac{f(L_n, S)}{|S|} \right) \left( \frac{L_m, S}{|S|} \right)
\]

where \( f(L_n, S)/|S| \) is the probability that the selected case belongs to class \( L_n \). All experiments and implementation were conducted in pycharm software. In this experiment the accuracy of the Accelerometer sensors System in determining Grazing, Standing and Ruminating chews was examined.

### Table 4
**Behaviour Types of Livestock**

<table>
<thead>
<tr>
<th>Behaviour Definition</th>
<th>Behaviour Denition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding Behaviour</td>
<td>Grazing</td>
</tr>
<tr>
<td></td>
<td>It is a method that allows cows to muzzle aloft the grass and makes biting pace to swallow grass.</td>
</tr>
<tr>
<td></td>
<td>Ruminating</td>
</tr>
<tr>
<td></td>
<td>The cows chewing, regurgitate and swallowing of ingested grass</td>
</tr>
<tr>
<td>Activity Behaviour</td>
<td>Standing</td>
</tr>
<tr>
<td></td>
<td>An upright position but is not walking</td>
</tr>
</tbody>
</table>

A continuous livestock behaviour monitoring framework was tried to record and visually detect five to six cows at a time on the basis of daily observation sessions. The total number of 60 observations were composed and also recorded in activity per daily observation session. The livestock behaviours visually observed were also recorded through an automated AC-Collar device. Both automatic observation and visual observations were compared using Pearson's correlation coefficient (r), Concordance correlation coefficient (CCC), and linear regression.

### Table 5
**Comparison of Experimental Techniques**

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>AC (min)</th>
<th>VD (min)</th>
<th>Bias (^1) (%)</th>
<th>r</th>
<th>CCC</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>253 (\neq) 62.6</td>
<td>205 (\neq) 51.6</td>
<td>10</td>
<td>0.82</td>
<td>0.63</td>
<td>0.12</td>
</tr>
<tr>
<td>Ruminating</td>
<td>27 (\neq) 28.3</td>
<td>44 (\neq) 31.1</td>
<td>04</td>
<td>0.79</td>
<td>0.71</td>
<td>0.34</td>
</tr>
<tr>
<td>Standing</td>
<td>270 (\neq) 80.1</td>
<td>222 (\neq) 70.9</td>
<td>11</td>
<td>0.91</td>
<td>0.72</td>
<td>0.18</td>
</tr>
</tbody>
</table>
5.1 Grazing Behaviour

The experimental result was compared between the results attained through AC-Collar (AC) and visual detection (VD) show in Table 5. The mean time spent grazing per cow per day recorded through AC was 253 min and VD was 205 min. Bias (%) was determined as: \( AC / 180, VD / 180 \times 100 \), where 180 is the total time (3h.) per daily observation session. The mean bias of grazing time among AC and VD results was 34 min. Compared to VD, AC results determined high grazing time (10% on average). AC results and VD results showed a robust correlation \( r = 0.82, \text{CCC} = 0.63 \) between each other with an RPE value of 0.12.

5.2 Rumination Behaviour

The mean rumination time per cow, per daily observation session recorded through AC, was 27 min and VD was 44 min. Compared to the VD, AC results described less rumination time (4% on average). The mean bias of rumination time per daily observation session among two techniques was 17 min. The AC and VD results described robust correlation \( r = 0.79, \text{CCC} = 0.71 \) with an RPE value of 0.34.

5.3 Standing Behaviour

The mean standing time per cow, per daily observation session recorded through AC, was 270 min and VD was 222 min. Compared to the VD, AC results described less rumination time (5% on average). The mean bias of rumination time per daily observation session among two techniques was 80.1 min. The AC and VD results described robust correlation \( r = 0.91, \text{CCC} = 0.72 \) with an RPE value of 0.18.

Overall, the results showed that AC-Collar is a consistent expedient to precisely monitor grazing, rumination and standing behaviours of livestock.

6. Conclusion

The emergence of IoT technology is fuelling the evolution of implementation of sensor and machine learning technologies in modern livestock farming. In the current scenario, it is a very challenging task for nutritionists, feed mills and water in 24/7 insights into the livestock’s activity. In the livestock farming sector such sensors have been the basis for the formation of decision support systems that improve farm operational efficiency. A proposed work presents the emerging IoT technologies in livestock farming and highlights the upcoming challenges. In the near future, the proposed system will integrate in the supply chain with intelligent analytic techniques that will help to take over some of the management and decision-making tasks of farmers and advisors. IoT has the potential to revolutionize livestock farming by improving efficiency, reducing costs, and increasing productivity. However, in order to fully realize its potential, challenges such as cost and lack of standardization must be overcome. Further research and development are needed to address these challenges and make IoT technology more accessible to farmers.

Declarations

**Ethical Approval**

Not applicable

**Authors’ contributions**
Funding

Not applicable

Availability of data and materials

Not applicable

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

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Figure 1

Highlights the Major Technologies

Figure 2

Proposed Model
Figure 3

Monitoring with Collar Device

![Monitoring with Collar Device](image)

Grazing time detected through AC-Collar & Visual Detection

Figure 4

![Graph showing grazing recorded minutes](image)
Figure 5

Ruminating time detected through AC-Collar & Visual Detection

Figure 6

Standing time detected through AC-Collar & Visual Detection