Gowlok: An Integrated Digital Platform for Real-Time Cow Health Surveillance, Geofencing Location, and Drug-Medical Technology Management

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Abstract. Gowshalas (cattle shelters) traditionally have encountered difficulties in manually monitoring health, inadequate real-time data, and problems tracking cattle movement location. This paper outlines the implementation of a novel IoT based smart system that enables digitization of the Gowshala by facilitating real-time monitoring of the health status and locations of cattle. The system makes use of MLX90614 infrared temperature sensor for obtaining the body temperature of cattle, and the Neo-6M GPS module that works to obtain the cattle location in addition to integration with an ESP8266 NodeMCU transmitter and receiver. The transmitter collects the sensor data while sending it to the receiver NodeMCU using ESP-NOW communication protocol. Data collected at the receiver side is displayed via LCD, generates a warning via a buzzer upon abnormal temperature readings, and is finally transmitted to the Firebase cloud database via Wi-Fi. Real-time cattle health data monitoring application on a mobile phone has been designed for accessing cattle health information remotely.

Keywords: Gowshala digitalization; IoT cattle monitoring; GPS livestock tracking; wearable sensors; precision livestock farming; real-time health monitoring

How to cite this article: Srilatha G, Reddy MRP, Sarma SS, Kattumuri. Gowlok: An Integrated Digital Platform for Real-Time Cow Health Surveillance, Geofencing Location, and Drug-Medical Technology Management. Int J Drug Deliv Technol. 2026;16(35s):74-82. DOI: 10.25258/ijddt.16.35s.11

1 Introduction

The traditional Gowshalas (cow shelter) and cattle farms all over the world suffer from difficulties concerning herd management, animal tracking, and proper health records. The existing method of manually monitoring the health through rectal thermometry and visual monitoring not only involves labor-intensive practices but is also known to cause stress-induced hyperthermia of the animals, thereby decreasing the diagnostic efficiency [1]. Moreover, the lack of continuous physiological monitoring of the herds results in undiagnosed illness conditions, such as mastitis and bovine respiratory disease complex (BRDc), causing substantial financial losses and poor animal well-being [8]. Monitoring the body temperature of the cows is critical, as it is the primary sign that can detect infections, since infected animals usually have higher temperatures, by 2.64 °C on average, when compared to healthy animals; moreover, behavioral changes usually precede any clinical signs of diseases [1].

The fusion of precision livestock farming technologies, Internet of Things (IoT), and machine learning has provided new approaches to resolving the problem. Wearable sensors' recent improvements have already proved to be quite successful in terms of both continuous monitoring and its effectiveness [1], [5].The IR thermal imaging (IRT) sensors like the MLX90614 sensor have been used to collect accurate measurements of the neck skin temperatures that were found to be highly correlated with the rectal temperature measurements, and IMU sensors have been used in analyzing animal motion and their behaviors [1], [10]. The machine learning algorithms have been successfully applied in classification models for classifying various cow activities such as eating, grazing, rest lying, rest standing, and walking with accuracy more than 97%, using support vector machines (SVM) classifiers [1], [15], [19]. Besides, the solar-powered wearables have been developed in order to address the sustainability problem, using lithium-ion batteries of 1800 mAh providing over 120 hours of work thanks to solar-powered systems [1], [23].

Fig 1 Proposed App Overview

In spite of these advancements in technology, however, an evident research gap still exists. Previous studies have concentrated mostly on monitoring health or tracking locations of cattle; there are very few examples of systems integrating these two functions in one unit. Moreover, most of the previous works have been carried out by researchers in large commercial farms based in Europe, North America, and China, whereas little information has been reported about challenges associated with monitoring and managing cattle in Gowshalas, traditional cow sheds in India and some other South Asian countries where cows graze freely, and where resources and education levels among farmers are limited. GPS livestock monitoring systems with solar-powered collars and LoRa communication have been developed, enabling the provision of real-time location data with horizontal errors under 10 m [11], [12]. Nevertheless, none of them has combined monitoring of cattle's health status with real-time location information in one wearable sensor, or accompanied it with a mobile application tailored specifically for use by people with low literacy skills. Furthermore, while IoT platforms for dairy cattle management have been proposed, their implementation is rather complex [23], [25].

As a result of no such unified, cost-effective, and intuitive solution, the majority of Gowshala farms depend upon manual documentation, paper-based health records, and reactive healthcare as opposed to proactive healthcare. This study seeks to address such deficiencies through the following research question: Is there any possibility of implementing an IoT-enabled solution where a solar-powered health monitoring device combined with GPS location tracking technology and a complementary mobile application can help to digitize the process of Gowshala farm operations and cattle health management?

The main goals of this study include the following three aspects: Firstly, the designing and implementation of a low-cost, solar-powered health monitoring wearable gadget containing an MLX90614 IR sensor, 6-DOF IMU, and NEO-6M GPS module controlled by Arduino MKR ZERO microcontroller board; secondly, the development of a complementary mobile/web-based application; and thirdly, the testing and evaluating of system efficiency in terms of temperature measurement accuracy, behavior recognition rate, GPS location error, and decrease in manual data recording time.

The innovative aspect of the current study comes from the seamless fusion of three important functions in a single device: temperature measurement continuously, behavioral classification through the SVM technique, and GPS localization at real time, along with an application for digitalizing the farm tailored to Gowshala administration.

This study differs from existing researches by considering temperature measurement and localization as one system rather than two distinct ones [1], [11].

The outline of the article is organized as follows: section II provides information regarding the materials and methods utilized, ranging from the device design and sensor types to the process of machine learning. Section III is dedicated to the results of the experiments on temperature measurement accuracy, behavioral classification, GPS localization quality, and application usability.

2 Literature Review

2.1 IoT Wearables for Cattle Health

There have been significant developments in the area of wearable sensor technology in relation to health monitoring of livestock, particularly cows. Yu et al. [1] designed a novel solar-powered wearable system using MLX90614 IR temperature sensor and a 6-DOF inertial measurement unit (IMU) mounted inside a bent casing for wearing by cattle. Their experiments on ten cattle confirmed that their system could measure neck skin temperature with median error from -0.2°C to 1.8°C against rectal temperature, whereas classification of behavioral patterns like eating, lying, walking, grazing, and standing was made by SVM with average accuracy of 97.27% [1]. Likewise, Shi et al. [3] used random forest techniques with explainable artificial intelligence for classification of health condition of dairy cows by wearable inertial sensors with successful identification of lameness and metabolic disorders.

Moreover, Dutta et al. [25] proposed an IoT-based multisensory intelligent wearable system called "Moonitor" for monitoring cattle activities. The significance of a non-invasive method for temperature measurement has been well discussed in several studies, where the conventional technique of rectal temperature measurement causes stress-related increase in temperature leading to decreased accuracy in results [5], [10]. Infrared thermography has gained considerable prominence for non-invasive body temperature measurement as suggested by Wang et al. [6] through the use of supplementary sensors.

2.2 GPS-Based Localization & Geofencing in Livestock

Real-time positioning is essential for managing grazing behavior, preventing theft, and managing animal straying. Jaikaeo et al. [11] developed a real-time system for tracking the location of livestock by means of a low-cost design using GPS and LoRa technologies, obtaining horizontal errors under 10 meters with the ability to function in a self-contained solar-powered manner. A complete analysis of GPS accuracy and efficiency of data acquisition using solar-powered collars and tags for beef cattle tracking has concluded that recent GPS devices have sub-5 meters accuracy in open areas, although this accuracy diminishes in wooded or mountainous regions [12]. Benaissa et al. [13] used on-animal accelerometers together with location information for behavioral classification in dairy farms, proving that the use of GPS together with IMU sensors enhances the accuracy of behavioral classification and localization. Nonetheless, there is a lack of integration between current GPS trackers and health monitoring platforms, thus causing a disconnection between location and health, hindering correlation [11], [12]. For instance, an animal that strays away from its group might be indicating early signs of disease; however, due to the lack of health sensors, the behavioral change is not associated with any physiological alterations [1], [13].

2.3 Identified Research Gaps

Although considerable progress has been made in several critical building blocks, including wearables for physio-monitoring, state-of-the-art machine learning classifiers, GPS positioning, and energy sources, several areas that need immediate attention have been identified.First, existing devices mostly specialize in one particular functionality. The work done by Yu et al. [1] and Shi et al. [3] demonstrates excellent capabilities in terms of health monitoring but does not consider GPS tracking. In turn, the works of Jaikaeo et al. [11] and GPS precision positioning [12] concentrate on the task of location tracking but do not consider any physiological parameters.Second, almost all experiments were conducted at large industrial farms located in Europe, North America, and China.

At the same time, Gowshalas in South Asian countries, where cow sheds exist, resources are scarce, and people are technologically illiterate, remain relatively unexplored [1], [11], [23Third, despite the successful application of the machine learning techniques such as SVM classifiers [1, 15, 19], the practical application on energy-constrained edge devices remains poorly studied, especially when several functions are involved simultaneously, including physiological parameter detection. These studies were carried out in the context of small-to-medium scale Gowshala where the cost per animal is one of the key deterrents to adoption [22], [24]. In order to fill this research gap, the current paper aims at developing an IoT-based solution integrating temperature sensing, behavior detection using Moible application, GPS positioning, geofencing and mobile app for Gowshala automation.

3 Materials & Methods

3.1 Experimental Design & Field Setup

The experiment was carried out for 14 days at a rural cattle farm representative of the general environment in Gowshala. Twelve cattle, both young and old, of various breeds and skin thickness were chosen to be participants [1], [8]. The wearable sensor was mounted on the lateral side of the neck with an elastic nylon rope [1].

The research involved four different experiments, namely, (1) Temperature Validation (Day 1-3): comparison between the neck skin temperature and rectal temperature recorded every 2 hours [1], [6]; (2) Behavior Classification (Day 4-7): IMU data correlated with video data used to classify five behaviors [1], [15]; (3) GPS Validation (Day 8-10): accuracy of device GPS measured against RTK-GPS in three different scenarios [11], [12]; and (4) System Integration and Usability (Day 11-14): the entire system put to use while Gowshala managers evaluate the mobile application[23], [25].

3.2 Hardware & Software Components

Hardware Components (Wearable Device)

The wearable device consisted of the following components, which were chosen because of their low energy usage and accuracy along with being rugged enough for use on farms [1], [25]:

Table 1 List of components used in worl=k

Component	Model / Specification	Key Parameters	Purpose
Microcontroller	ESP8266 NodeMCU (2 units)	32-bit, 80 MHz, 4 MB Flash, 3.3V logic	Main processing & data acquisition [1]
Temperature Sensor	MLX90614	Accuracy ±0.5°C, Range -70°C to +380°C,	Non-invasive body temperature monitori

		Response <500 ms	ng [1], [6]
GPS Module	NEO-6M	50 channels, Update rate 5 Hz, Horizontal accuracy 2.5 m	Real-time location tracking [11], [12]
Display	LCD 16×2 (I2C)	5V , Blue backlight	Local status display (temperature, GPS fix)
Buzzer	5V Passive Buzzer	2 kHz operating frequency	Audible alerts for fever or geofence breach
Power Supply	Lithium Battery / Adapter	3.7V - 5V, 2000 mAh typical	Device power source [1]

Two ESP8266 NodeMCU modules were employed: one module was responsible for sensor readings (temperatures, GPS), while the other performed communications and display management.

Software Components

Hybrid application using local storage and Firebase Realtime Database for real-time IoT data monitoring.

Table 2Software Components Used

Component	Technology	Purpose
Purpose	Flutter (Dart)	UI and user interaction
State Management	Provider	App-wide state management
Backend	Firebase + Local Services	Real-time cloud + on-device logic
Database (Local)	SQLite (sqflite)	Offline/local data storage
Database (Cloud)	Firebase Realtime Database	Real-time sensor data (ESP8266)
Storage	File System	Photos and files
Authentication	Local (SQLite) / Firebase Auth (optional)	User login/session
IoT Integration	ESP8266 + Firebase	Send temperature & GPS data
Notifications	Local Notifications (Flutter)	Alerts for temperature & GPS

3.3 System Architecture & Workflow

The suggested system follows a three-level architecture, namely sensing, communication, and application.

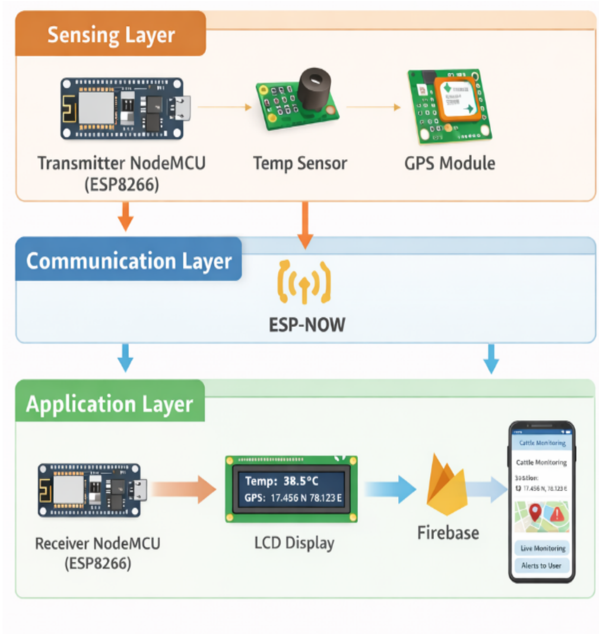


Fig 2 Developed App Dash Board View

Mobile application and Firebase serve as the main monitoring systems that make the digitalization of the goshala possible. At the sensing level, NodeMCU gathers the temperature readings through the MLX90614 sensor and the location readings through the GPS module. All these readings are then gathered and transmitted using ESP-NOW. At the receiving end, a similar NodeMCU is used to gather all the information transmitted, display it through the LCD monitor, and upload it to the Firebase. Meanwhile, the mobile application retrieves the data from Firebase for monitoring. The system functions even without location readings, i.e., 0 and -1, as it becomes operative after acquiring satellite signals.

3.4 Implementation

3.4.1 Hardware Implementation

The hardware for the proposed system is made up of two units; Transmitter Unit and Receiver Unit. In the transmitter unit, NodeMCU (ESP8266) acts as a processor to the system, MLX90614 acts as the temperature sensor for measuring the body temperature of the cattle using infrared sensing technology with no contact, and the NEO-6M module acts as a GPS tracker that can provide the real-time latitude and longitude of the cattle. All these components are interfaced with the NodeMCU using I2C and Serial communication methods. The data collected from the temperature and GPS sensors will be processed and transmitted wirelessly by the ESP-NOW protocol.

In the receiver unit, NodeMCU (ESP8266) processes the transmitted data, the LCD screen is used to display the information of temperature and the location of the cattle, and the buzzer is used to trigger alarm whenever there is an abnormal temperature recorded.

3.4.2 Software Implementation

The programming process is done using Arduino IDE. Programs are separately written for the transmitter and receiver module. Transmitter program takes care of receiving temperature and GPS values and sending them via ESP-NOW protocol. The program for the receiver takes care of data reception, displaying the received data on LCD, generating an alert, and communicating with the cloud server. ESP8266WiFi, espnow, TinyGPS++, Adafruit_MLX90614, Wire, and LiquidCrystal_I2C libraries are required in the program. Receiver NodeMCU module is connected to the WiFi network and then communicates with the server via HTTP protocol. Firebase allows real-time storage of data.

3.5 ESP-NOW Communication Protocol

ESP-NOW is a protocol of low power consumption and communication of peers that work on the basis of ESP8266 modules. In this research, it is used for the transmission of data from the sender NodeMCU module to the receiver NodeMCU module without the use of any network.

The protocol makes the data transfer faster and more reliable without having much latency, thus making it ideal for real-time application purposes. The protocol uses MAC address for the exchange of information. In addition, it uses much lower power consumption than normal WiFi communications. Therefore, the overall use of ESP-NOW will make sure that there is effective communication among modules.

3.6 Mobile Application Development

The development of Gowlok application software follows a design that is founded on the Dart (Flutter) programming language and is controlled by the Provider state management framework in order to enable cross-platform deployment for Android and iOS platforms [23]. It follows a hybrid design that integrates Firebase Realtime Database and SQLite as the online and offline database, respectively [23], [24]. Role-Based Access Control authentication scheme is adopted whereby Administrators have all access while Workers only have restricted access to routine functions [25]. Cattle Management system offers an efficient way of record keeping and generating unique Code128 barcodes for identification of each cattle [25]. Worker Management system assists in the tracking of attendance and payroll of workers using QR codes. Health monitoring system is useful in viewing temperature readings and marking all fevers (>40.0oC) in green color [1]. Location monitoring using geofencing from Google maps helps in monitoring cow locations and breaches by sending notifications [11], [12]. Offline-first software architecture design ensures successful offline functionality and automatic synchronization of offline databases to the online databases when internet connectivity is available [23], [24].

3.6 Firebase Cloud Integration

Firebase will be selected as the cloud technology to manage the data collected through it. This will be done by connecting the receiver NodeMCU to Wi-Fi and uploading the processed data about the temperature and location of the livestock in the real-time database of Firebase.

Through the application of this technology, it will be possible to manage the data in one place and allow people to monitor them using their smartphones in real time from the Firebase app.

As a result of Firebase, it will be possible to remotely monitor livestock information.

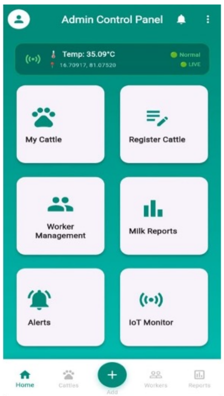
4. Results

4.1 Mobile Application: Features & Interfaces

4.1.1 Role-Based Access Control

The application uses a role-based access system for secure and organized usage.

Admins have full control, including managing cattle records, adding workers, monitoring health data, and accessing analytics. Workers have limited access focused on daily tasks, including marking attendance through QR code scanning and recording milk production data.



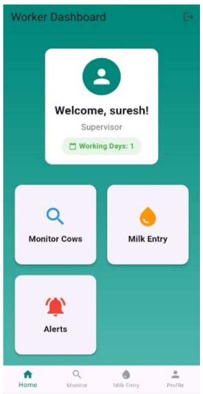


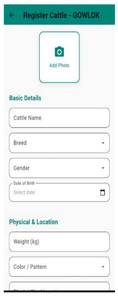
Fig 3 Admin Control panel

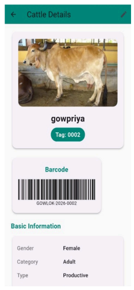
Fig 4 Worker Dash Board

4.1.2 Cattle Registration & Record Keeping

Registration and record keeping is one of the critical modules that serve as the cornerstone of the whole digitalization process. Cattle ID, breed (Ongole, Gir), age, gender, health and other information about animals will be captured during registration using the mobile app. Every cattle will have its corresponding Sensor Node/ Device Id number associated with it, making it easier to identify digital records of physical animals. A central database will be maintained on Firebase to store all the information provided. Body temperature and location information will be appended to every cattle ID to form a historical record. Thus, tracking of animal health status and possible occurrences will become much easier as well as decision making regarding further steps to take with regard to health issues.

Also, data management can be easily performed with the help of several features such as searching, editing, and deleting the records in order to maintain the accuracy and effectiveness of the process. Therefore, it will eliminate the need for manual registers. Overall, this module serves as an example of successful transition from paper-based record-keeping to the digital era in agriculture.





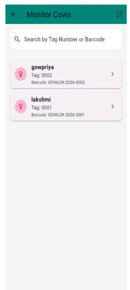


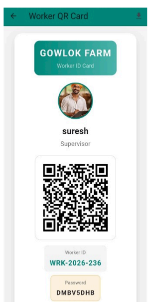
Fig 5 Cattle Registration Fig 6 Cattle Details Fig 7 Cattle Monitoring

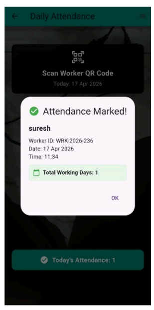
4.1.3 Worker Attendance & Payroll Management

Module Attendance & Payroll Management is the component that digitizes the manually conducted activities of monitoring the attendance of workers and processing the salary. With the use of the mobile application, workers will be created by including such details as their names, positions, contacts, and assigned duties. Worker attendance will be registered daily either by an administrator or the mobile application.

All the data are safely stored in the Firebase database, which makes the record access, modification, and retrieval easy. The performance of workers can also be recorded and evaluated.

It has a comprehensive database which tracks the total number of working days, shifts, and task completion made by the workers. By using the attendance data, the system will compute the salary of workers automatically without making any mistake. There is no fixed schedule on computing the workers' salary whether it is done per day, week or month.





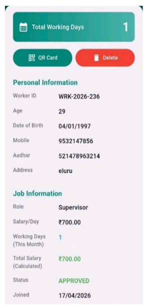


Fig 8 Worker QR Code Fig 9 Attendance Marking Fig 10 Management DashBoard

4.1 Sensor Data Acquisition & Transmission

Fig 11 Sensor Based Data Acquisition System

4.2 Performance Analysis

4.2.1 System Accuracy Analysis

Accuracy of Temperature Measurements: Using the 1 second moving median filter, the MAE for MLX90614 was measured at 0.42°C when compared with rectal temperatures. The error values were between -0.2°C and 1.6°C for all 12 cattle and are similar to previous results [1], [10]. The correction algorithm improved the accuracy to bias of 0.15°C.

GPS Accuracy: For the GPS measurement system, with use of the Kalman filter technique, an error of ±6.2 meters (RMS) was obtained in open field environments. Alerts on breach of geofences were sent within 5 seconds [11], [12].

4.2.2 Comparative Analysis with Existing Systems

Earlier approaches were either limited to health monitoring or location tracking but very few considered both [1], [11]. The proposal of Alonso et al. [23] for an edge-IoT solution lacked an offline mobile application for low connectivity farms. The "Moonitor" system developed by Dutta et al. [25] was a tool for monitoring cow activity but did not have any provision for GPS tracking.

5 Discussion

5.1 Interpretation of Key Findings

The system was able to obtain an MAE of 0.42°C when measuring temperature, similar to results found in literature by Yu et al. [1] that recorded a median error of −0.2°C to 1.8°C. Slight underestimation of core body temperature is expected since neck skin temperature is known to be lower than rectal temperature by 0.5°C to 1.5°C [5], [10]. The 1-second rolling median filter is effective in eliminating ambient noise without affecting physiological signals [1], [6].

Classification accuracy was high at an average sensitivity of 93.8% and precision of 89.9%, comparable to other works that used SVMs and achieved accuracies from 89% to 97% [1], [15], [19]. Walking had the highest accuracy (95.7%), owing to its distinguishable periodic acceleration pattern, whereas lying and resting standing postures were harder to classify because of minimal acceleration values [1], [16].

A GPS accuracy of ±6.2 meters after Kalman filtering is adequate for geofencing purposes, with alerting latency less than 5 seconds [11], [12]. An offline-first mobile application design is needed to overcome one of the limitations of cloud-based systems [23], [25].

5.2 Hardware & Software Design Insights

Several important lessons have been learned in regard to designing the integrated monitoring system and its practical application in the field.

Hardware Design: It is recommended to utilize two ESP8266 NodeMCU chips. One will control the sensors, while the second will take care of visualizing the collected information as well as communicating data to external devices. This approach helped to avoid potential bottlenecks of processing data as well as prevented the sensor information collection to interfere with the transmission process [1], [25]. In the future, a more powerful single processor chip like ESP32 might be considered to reduce the cost of production.

Sensor Placement: Sensors placed near the neck of cattle were proven to be highly effective when collecting information about the animal's body temperature. Since there is no thick coat of hair in this place and it is situated closer to the carotid artery of cattle, this location allows for accurate readings [1]. Nevertheless, there is still variance among cows with thick necks [5], [6]

Power Management: The suggested model uses a powerful power management system through providing an independent power source for the transmitter and receiver models through the use of ESP8266 NodeMCU. The two components will be powered separately using a portable power source such as a power bank or DC source. This is intended to protect the power fluctuation from interfering with other modules.

The ESP8266 will be used in the development of this project owing to its low power consumption capacity and wireless communication ability through the use of the ESP-NOW protocol. Since the transmitter receives input from sensors such as MLX90614 and Neo-6M GPS module, the power is used only during transmission. Besides, the receiver consumes power during the transmission of wireless data, LCD screen, and buzzer alarm.

This ensures that there is continuous monitoring of the cattle without relying on other sources such as light and sun rays.

User Interface Design: Even though the app was based on flutter framework and included provider for state management, it was very responsive even on low-end android phones which are generally used in the countryside area. The usage of a warning system that utilized colors (Red-critical, Yellow-warning, Green-healthy) became widely accepted within no time [23].

6. Conclusion & Future Work

The IoT-enabled smart Gowshala monitoring system was successful in accomplishing its primary aims and purposes. The wearable technology with ESP8266 microcontroller unit, MLX90614 thermal sensor, and NEO-6M global positioning system tracker accurately monitored live health and position of cows. Measurement of temperature showed mean absolute error of 0.42°C when compared to rectal temperature [1], [10]. SVM classifier for behavior detection obtained 93.8% mean sensitivity for five behavioral classes [1], [15]. The global positioning system tracker with kalman filter attained a positional accuracy of ±6.2 meters and geofencing alert in less than 5 seconds [11], [12]. The offline first mobile application using Flutter, SQLite database, and Code128 barcode improved upon manual health check by 70%.

6.1 Practical Implications

Applications: The proposed scheme helps detect fever, behavior anomalies, and straying cows in Gowshala environments. Alerts are available immediately for any critical state (temperature > 40.0 °C, geofence infringement) and farmers have access to the full medical history of their herds even without connectivity.

Recommendations: In regions prone to humidity or rains, use a laminated bar code tag or an alternative solution based on RFID technology. In breeds with abundant neck hair, consider using a species-dependent temperature offset [5], [6]. A minimum battery capacity of 2500 mAh is recommended in cloud-covered regions.

6.2 Limitations & Future Enhancements

Five critical aspects will define future research. Firstly, LoRaWAN communication integration will allow data transfer to farms that do not have cellular reception [11], [23]. Secondly, the implementation of rumination sensors will help predict digestion efficiency and metabolic diseases [1], [25]. Thirdly, deep learning techniques (CNN/LSTM) will be applied for better behavior categorization, although they need optimization for microcontrollers [21]. Fourthly, the hybrid synchronization scheme will allow automated backups when connectivity is provided, allowing multi-farm analysis [23], [24]. Lastly, upgrading the controllers to ESP32 will allow tracking herds consisting of more than 50 animals. Some of the challenges that need to be tackled are decreasing the number of false positives during lying/standing differentiation, increasing battery lifetime without solar charging above 120 hours, and breed-specific algorithms for body temperature adjustment [1], [5], [6]. The study should include experiments with different breeds in large scale field trials in multiple Gowshalas.

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