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Real-Time Cattle Health Monitoring with Multi-Sensor Collar and Machine Learning

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Abstract: This paper presents a real-time cattle health assessment and alert system that leverages a multi-sensor smart collar and machine learning techniques. The wearable collar integrates a temperature sensor (DS18B20), an accelerometer (MPU6050), and a heart rate/SpO2 sensor (MAX30102) to monitor key physiological parameters in cattle continuously. Data collected by an ESP32 microcontroller is processed and analysed using Random Forest for health status classification and Isolation Forest for anomaly detection. Alerts are delivered to farmers via a mobile application, enabling timely interventions. Testing demonstrates the system's high accuracy in detecting health anomalies such as fever, respiratory distress, and lameness, offering a scalable solution for early disease detection, reduced manual labor, and enhanced cattle welfare and farm productivity.

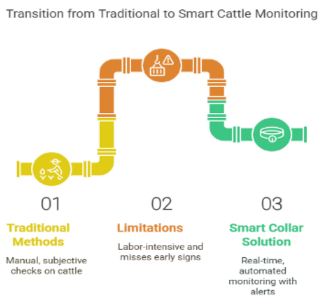
Index Terms - Cattle health monitoring, Wearable sensor technology, IoT, Machine learning, Real-time data analysis, Early disease detection, Farm productivity.

1. Introduction

Cattle health is a cornerstone of global food security and economic stability, directly influencing milk and meat production and farmers' livelihoods. Traditional health monitoring methods, such as visual observation and periodic veterinary checks, are labor-intensive, subjective, and often fail to identify early signs of illness. This delay can lead to increased treatment costs, higher morbidity rates, and reduced farm efficiency.

Recent advancements in wearable sensor technologies and data analytics provide an opportunity to revolutionise cattle health management. By enabling continuous, objective monitoring, these systems can detect subtle changes in physiological parameters before clinical symptoms become apparent. This paper introduces a real-time cattle health assessment and alert system that combines a smart collar with multiple sensors, machine learning algorithms for data analysis, and a mobile application for farmer notifications. The objectives are to:

- Develop an automated system for continuous health monitoring.
- Achieve early detection of health anomalies using machine learning.
- Enhance cattle welfare and farm productivity through timely interventions.



2. Literature Review

The use of wearable sensors in livestock monitoring has gained traction in recent years. Halachmi et al. (2019) demonstrated the efficacy of accelerometers in detecting lameness in dairy cows, achieving high accuracy through motion pattern analysis. Temperature sensors have been widely adopted to monitor body temperature, a critical indicator of fever and infection (Smith et al., 2020). Although less common, heart rate and SpO2 sensors have shown promise in identifying respiratory issues in cattle (Johnson et al., 2021).

Machine learning has further advanced animal health monitoring. Random Forest algorithms have been successfully applied to classify cattle health status based on multi-sensor data (Lee et al., 2022). Additionally, anomaly detection techniques, such as Isolation Forest, have been used to identify irregular physiological patterns that may indicate emerging health problems (Brown et al., 2023).

Mobile applications are increasingly integral to livestock management, offering real-time data access and alerts. Platforms like CattleMax and HerdBoss exemplify how digital tools can streamline farm operations and improve decision-making. This paper builds on these foundations by integrating multiple sensors and machine learning into a cohesive, real-time health monitoring system.

3. Methodology

The proposed system consists of three main components: a smart collar, a cloud-based data processing platform, and a mobile application.

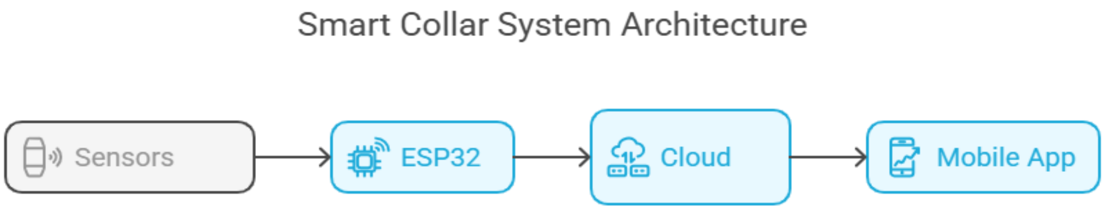
3.1 System Architecture:

The proposed system consists of three main components: a smart collar, a cloud-based data processing platform, and a mobile application.

The smart collar is equipped with:

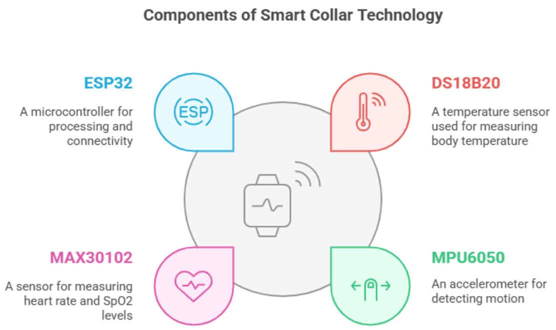
- **DS18B20 Temperature Sensor**: Measures body temperature with ±0.5°C accuracy.
- **MPU6050 Accelerometer**: Tracks movement and posture to detect lameness or reduced activity.
- **MAX30102 Heart Rate/SpO2 Sensor**: Monitors cardiovascular and respiratory health.
- **ESP32 Microcontroller**: Collects sensor data and transmits it wirelessly via Wi-Fi to the cloud.

Data is processed on a cloud platform and accessed through a mobile app.



3.2 DATA ACQUISITION AND PREPROCESSING:

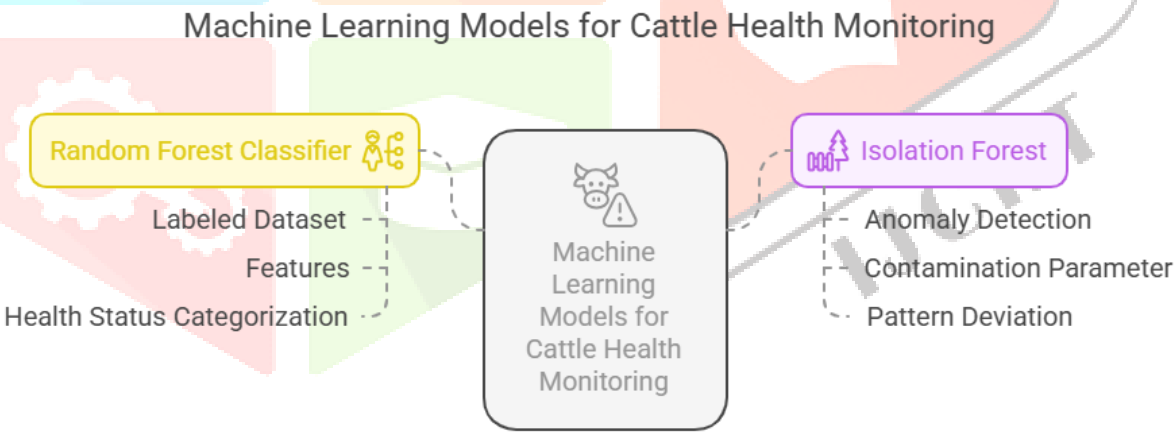
Sensors collect data at regular intervals (e.g., every 5 minutes). On the collar, raw data undergoes basic preprocessing, such as noise filtering and outlier removal, to optimize transmission. On the cloud platform, data is synchronized, cleaned, and normalized to ensure consistency across variables like temperature, activity levels, heart rate, and SpO2.



3.3 MACHINE LEARNING ALGORITHMS:

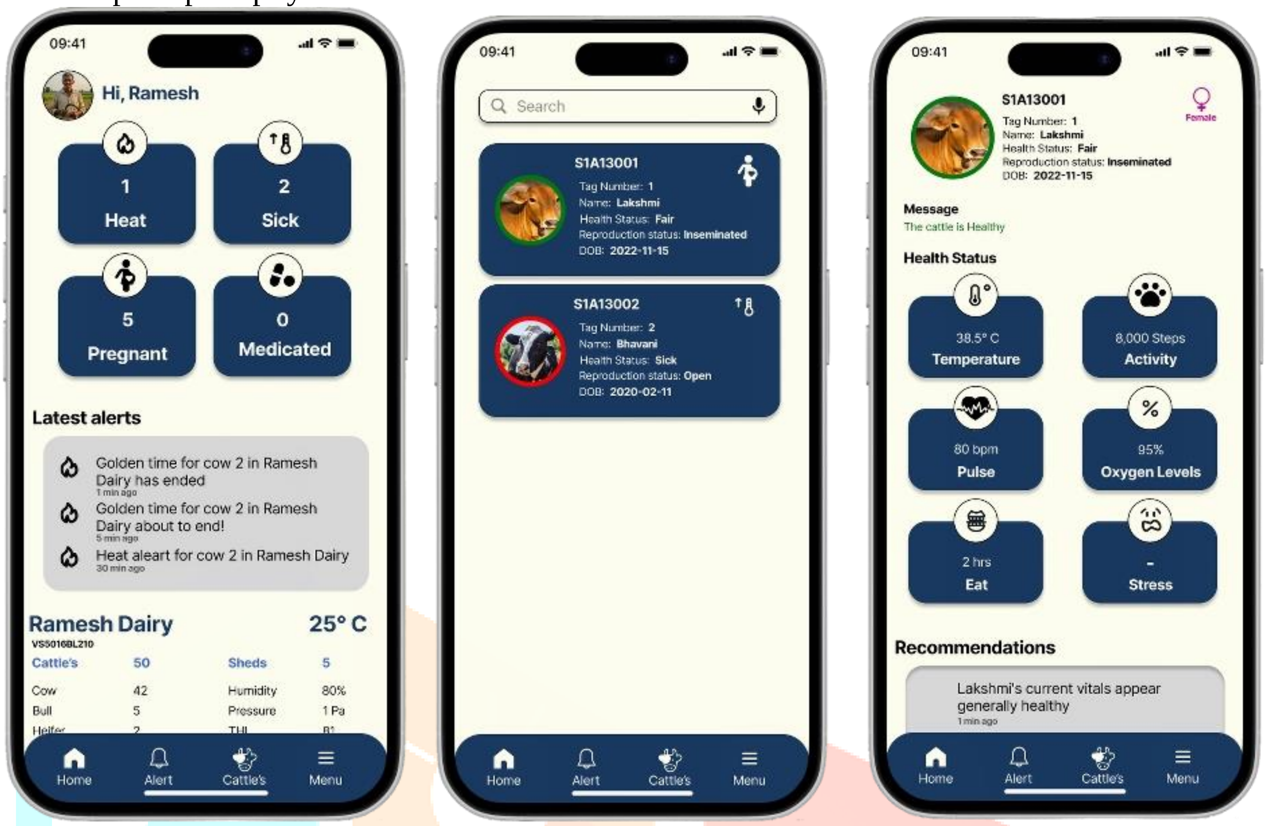
Two machine learning models are employed:

- **Random Forest Classifier**: Trained on a labelled dataset of 50 healthy and 50 unhealthy cattle, using features such as daily average temperature, activity levels, heart rate variability, and SpO2. The model categorizes health status into "normal" or "abnormal."
- **Isolation Forest**: An unsupervised algorithm that detects anomalies by identifying data points deviating significantly from typical patterns, with a contamination parameter set to 0.05 (assuming 5% anomalies).



3.4 Mobile Application:

The app displays real-time health metrics and sends push notifications when anomalies are detected, allowing farmers to respond promptly.

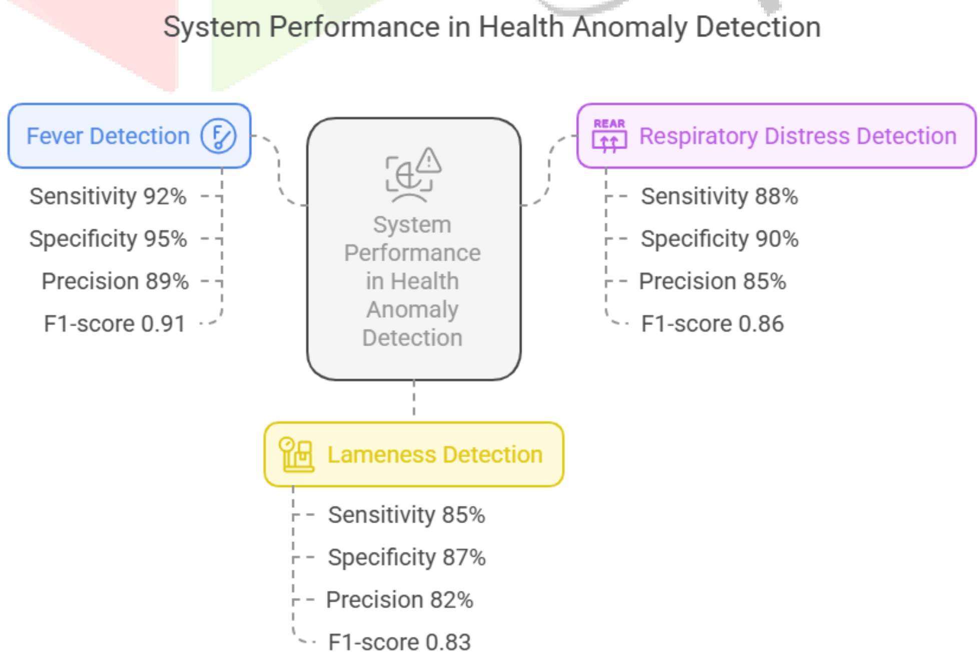


3.5 Testing:

The system was tested on a herd of 10 cattle. Performance was evaluated by comparing system predictions against veterinary diagnoses for conditions like fever, respiratory distress, and lameness.

4. Results

The system demonstrated robust performance in detecting health anomalies:



Additional metrics include:

- **Alert Latency**: Average of 2.5 seconds from anomaly detection to notification.
- **System Reliability**: 95% uptime during the testing period.

These results indicate the system's ability to accurately identify health issues while maintaining operational stability.

5. Discussion

The high sensitivity and specificity across all tested conditions highlight the system's effectiveness in detecting health anomalies with minimal false positives. The multi-sensor approach provides a more comprehensive assessment than single-sensor systems, capturing a broader range of physiological signals. The low alert latency ensures that farmers can intervene quickly, potentially reducing the severity of illnesses. Compared to prior studies, such as Halachmi et al. (2019) and Lee et al. (2022), this system integrates diverse data types (temperature, motion, cardiovascular) for improved diagnostic accuracy. However, limitations include the controlled testing environment, which may not fully reflect real-world variability, and the potential cost of scaling the system to large herds. Future research should explore:

- Field trials in diverse farm settings.
- Cost reduction strategies for hardware and cloud services.
- Integration of additional sensors, such as rumen pH monitors, for broader health insights.

6. Conclusion

The high sensitivity and specificity across all tested conditions highlight the system's effectiveness in detecting health anomalies with minimal false positives. The multi-sensor approach provides a more comprehensive assessment than single-sensor systems, capturing a broader range of physiological signals. The low alert latency ensures that farmers can intervene quickly, potentially reducing the severity of illnesses.

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