Smart Cattle Health Monitoring: IoT for Sustainable Farming

Welcome to the presentation on our innovative IoT-based cattle health monitoring system designed to revolutionize sustainable farming. This system enables real-time insights, facilitates early disease detection, and offers scalable solutions tailored for farms of all sizes. Our goal is to introduce a technology-driven approach that enhances animal welfare, reduces economic losses, and optimizes farm management.

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Challenges in Traditional Cattle Health Monitoring

Labor-Intensive Manual Checks

Farmers currently rely on periodic manual inspections, which are time-consuming and often result in delayed disease diagnosis. This reactive approach limits timely intervention, impacting animal health and farm productivity.

Environmental factors such as ambient temperature and humidity, which significantly affect cattle health, remain largely unmonitored with conventional methods.

Manual data recording is prone to errors and inconsistencies, further complicating accurate health assessment and decision-making.

Economic Consequences

Untreated illnesses lead to substantial economic losses yearly due to reduced milk yield, increased veterinary costs, and potential livestock fatalities. Early detection remains a critical unmet need to mitigate these risks.

Implementing a tech-enabled solution to address these challenges presents a promising pathway to enhance efficiency and profitability in livestock farming.

Long downtime in treatment due to late diagnoses contributes to escalating operational costs and loss of valuable livestock assets.

Limited Data and Insights

Traditional methods provide limited data points, making it difficult to accurately track and predict health trends within the herd.

This lack of continuous monitoring impedes proactive management, increasing the likelihood of outbreaks and chronic health issues going unnoticed until they become severe.

Moreover, the absence of integrated health records restricts the ability to identify patterns linked to nutrition, breeding cycles, or environmental stressors.

An IoT-Driven Solution for Continuous Health Monitoring

Real-Time Vital Sign Tracking

Non-invasive sensors continuously monitor heart rate, blood oxygen saturation, skin temperature, and environmental conditions, enabling seamless data collection without disturbing the cattle.

Behavior Classification & Wireless Alerts

Advanced motion sensors classify cattle behaviors such as grazing and resting with high accuracy, while wireless communication protocols (Wi-Fi and LoRa-WAN) provide timely alerts for abnormal conditions.

System Architecture

Data flows from wearable sensors to an ESP32 microcontroller, which transmits it to a cloud platform, allowing centralized monitoring through a user-friendly dashboard.

Advanced Technologies Enabling Precision Monitoring

MAX30100 Sensor

Measures heart rate and blood oxygen saturation with ±2% accuracy using PPG technology for non-invasive monitoring.

MLX90614 Sensor

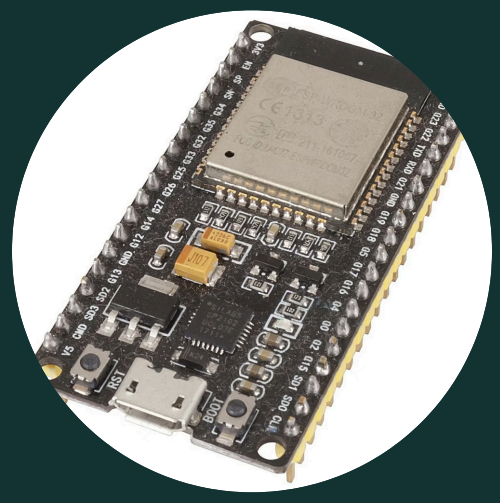
High-precision non-contact skin temperature measurement with ±0.3°C accuracy for early fever detection.

ADXL345 Accelerometer

Tracks movement and orientation to classify behaviors like grazing or resting with ±0.02g resolution.

DHT22 Sensor

Monitors ambient temperature and humidity to assess cattle comfort and detect environmental stress.



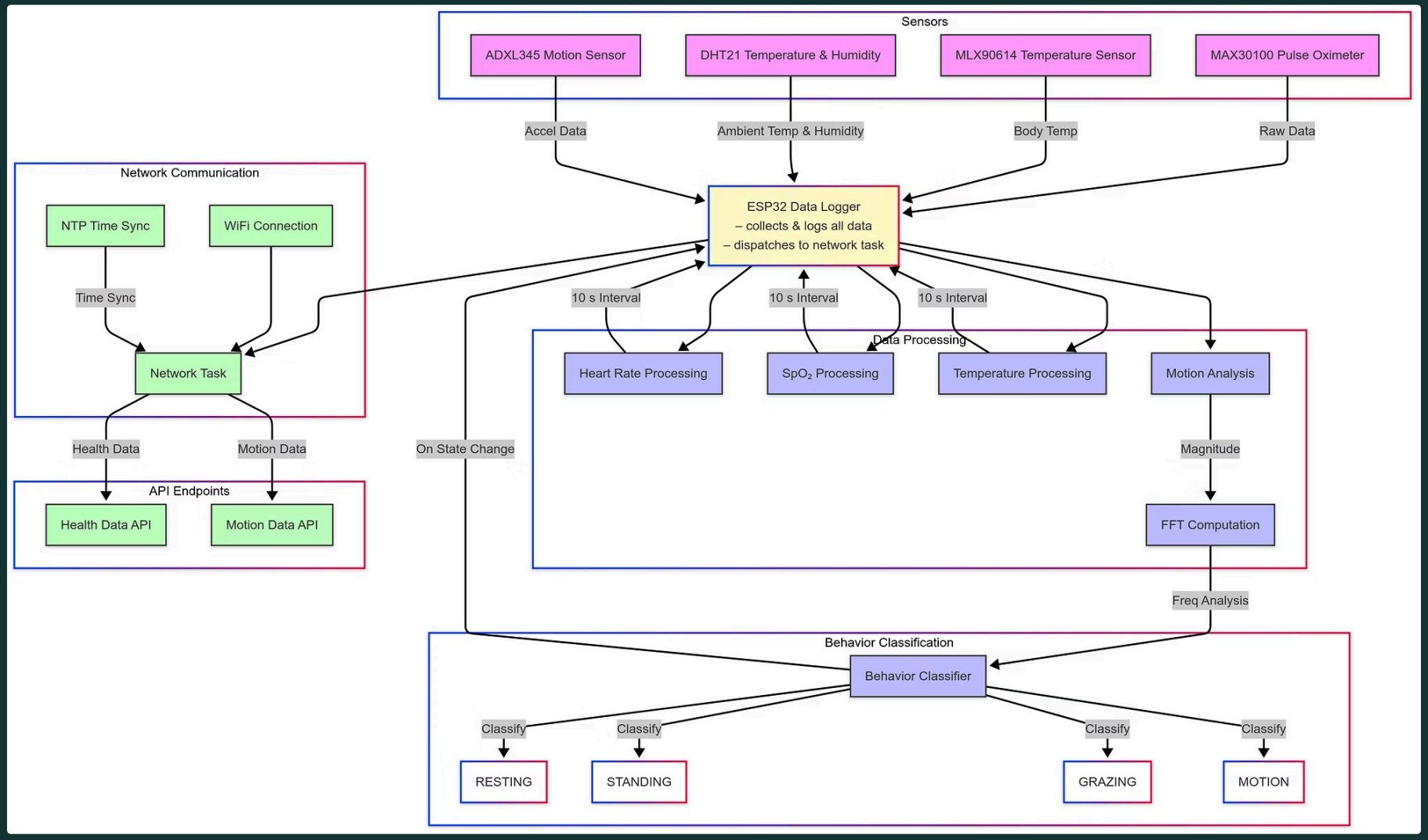
ESP32 Microcontroller

Integrates Wi-Fi and LoRa-WAN connectivity with low-power modes for reliable, energy-efficient data transmission.

Validation and Sensor Performance Metrics

Sensor	Measured Parameter	Interface	Calibration Standard
MAX30100	Heart Rate, SpO_2	I^2C	Veterinary oximeter
MLX90614	Skin Temperature (IR)	I^2C	Clinical thermometer
DHT22	Ambient Temp & Humidity	1-wire	Digital hygrometer
ADXL345	Tri-axis Acceleration	I^2C/SPI	Motion test rig

System Architecture Flowchart:



Innovations Driving Accurate Health Analytics

Non-Invasive Temperature Estimation

This system estimates rectal temperature using an empirically validated formula that combines skin and environmental temperatures. It achieves a mean absolute error (MAE) of ±0.4°C, providing clinically relevant accuracy without invasive procedures.

Rectal Temperature Estimation Equation:

· rectal = 0.82 ·skin + 0.13 ·env + 0.03H + 2.1

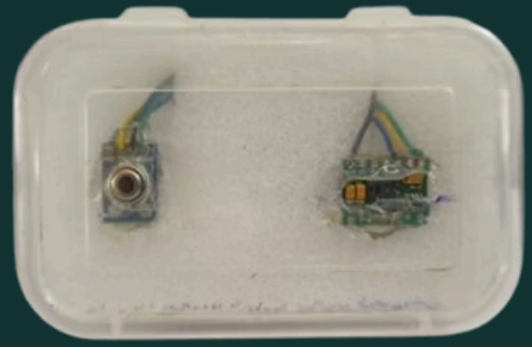
Behavior Classification Algorithm

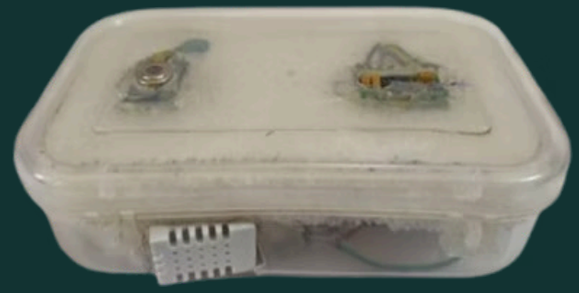
By applying machine learning techniques to ADXL accelerometer data, the algorithm accurately distinguishes behavioral states such as grazing, resting, standing, and motion. It achieves over 92% classification accuracy, which is essential for effective health and welfare monitoring.

The algorithm processes continuous movement data to identify specific patterns reflecting different activities. This allows for timely detection of deviations from normal behavior, which can indicate illness or distress. Implementing such classification supports proactive intervention, reducing health risks and improving cattle management efficiency.

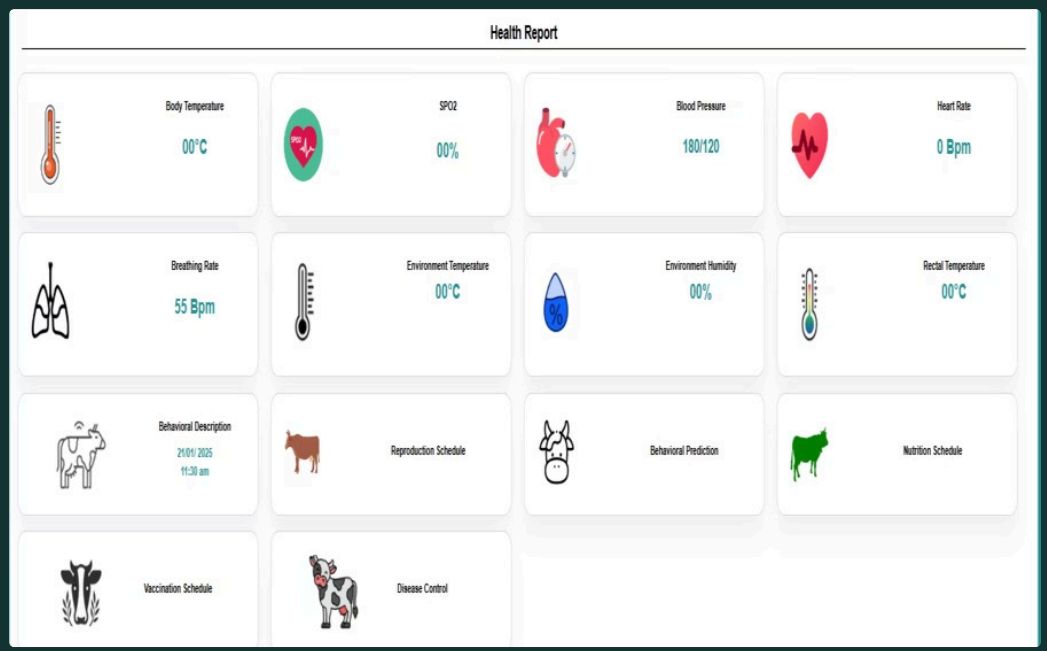
Hardware Model(prototype)

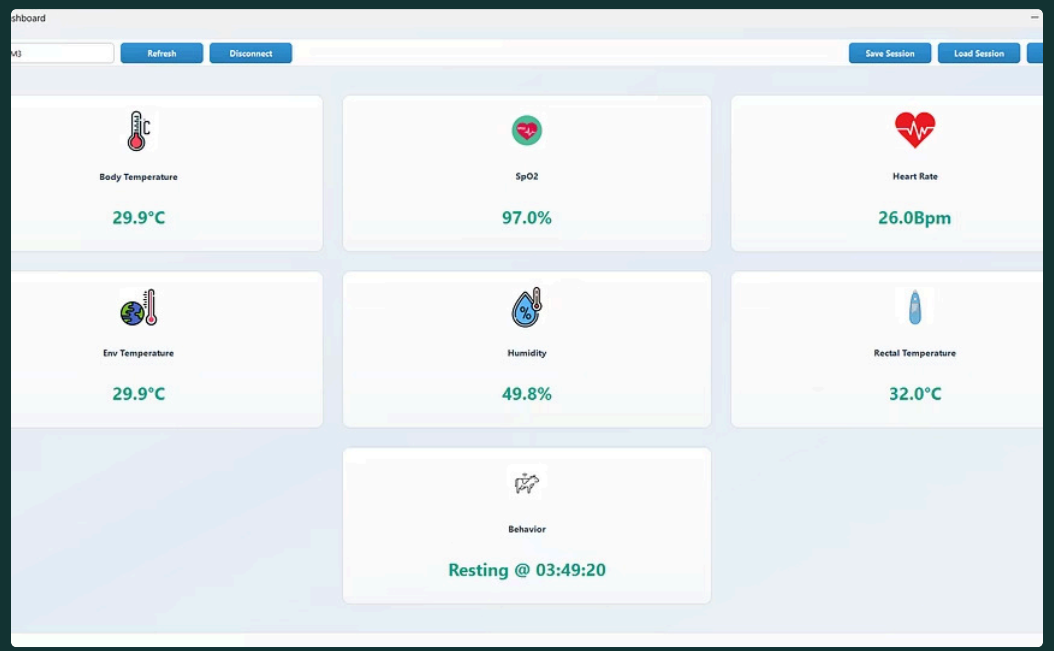
We validated each sensor against clinical benchmarks: the MAX30100's SpO_2 and heart - rate readings did not deviate more than ±2 bpm and ±2 % SpO_2 from a veterinary - grade pulse oximeter. The MLX90614 infrared thermometer maintained temperature accuracy within ±0.5 °C compared to a medical forehead thermometer . The DHT22's measurements of ambient temperature and relative humidity were within ±0.5 °C and ±2 % RH of a calibrated laboratory hygrometer . For motion tracking, the ADXL345 accelerometer delivered 3.9 mg resolution—equivalent to ±0.02 g—suitable for classifying bovine behaviours. All sensors interface over I^2C or SPI to an ESP32 development board, which in our prototype is powered directly via its USB port (5 V through the onboard regulator) or—alternatively—by a regulated 3.3 V supply connected to the 3V pin.





Integrated Dashboards for Real-Time and Offline Monitoring





Online Dashboard (Grafana)

- Intuitive real-time charts showcasing vital signs and behavioral pie charts for quick assessment
- Configurable threshold alerts via SMS and email to promptly notify farmers of abnormal conditions
- Supports remote centralized monitoring of multiple farms through a cloud-based platform
- Customizable views adapt to different farm sizes and priorities for improved management efficiency
- Secure user access controls ensure data privacy and role-based permissions

Offline Desktop App (PyQt5/SQLite)

- Operates independently in low-connectivity or disconnected environments for uninterrupted monitoring
- Local SQLite database ensures data integrity, reliable storage, and persistent accessible alerts
- Automatic synchronization with the cloud post network restoration guarantees up-to-date information
- User-friendly interface designed for easy navigation by farmers with minimal technical expertise
- Provides historical data review and report generation in offline mode to support decision making

Sensor Data Comparison

Timestamp	Behavior	SpO2	Heart Rate	Body Temperature (°C)	Env Temperature (°C)	Humidity (%)	Rectal Temperature (°C)
2025-04-23 00:15:17	0	0	0	33.41	33.7	63.9	35.79
2025-04-23 00:15:57	2	97	105	33.85	34	58.7	36.04
2025-04-23 00:16:37	2	0	0	34.31	34.1	58.9	36.43
2025-04-23 00:17:57	2	97	6	33.07	34.2	58.3	35.41
2025-04-23 00:18:07	0	0	6	36.37	34.2	51.9	37.93

This table displays key sensor outputs over time including SpO2, heart rate, and temperature.

Combined data streams enable precise health assessment and behavior tracking.

Transforming Farm Operations: Farmer Benefits

Early Disease Detection

Real-time monitoring detects mastitis up to 48 hours before visible symptoms through continuous heart rate and temperature analysis, reducing veterinary costs by 30%.

Labor Efficiency

Automated 24/7 health and behavior tracking using accelerometer and environmental sensors minimizes manual inspections by 70%, allowing farmers to focus on higher-value tasks.

Scalability & Adaptability

Modular IoT hardware and cloud-based analytics support easy expansion from small family farms to large industrial operations, accommodating varying herd sizes and environments.

Conclusion & Next Steps

Validated & Field-Tested

Our system delivers clinically validated health monitoring with proven sensor accuracy and behavior classification in real farm environments.

Flexible & Reliable Monitoring

Dual-mode dashboards provide continuous monitoring capabilities, catering to diverse connectivity scenarios encountered in farming.

Sustainable & Scalable Impact

Designed for global adoption, our modular solution fosters sustainable livestock management while reducing labor and economic losses worldwide.

Empowering farmers with smarter livestock care for a healthier, more productive future.

Roadmap for Future Enhancements

2025: Solar-Powered IoT & LoRa-WAN

Develop solar-based power solutions and expand connectivity to off-grid, remote farms using LoRa-WAN technology.

2024-2025: TinyML & GPS Integration

Integrate GPS tracking and implement on-device TinyML models for advanced behavior analytics and precise animal localization.

2025: Farmer Mobile App

Design and launch a mobile app enabling farmers to receive push notifications, visualize data, and interact with the system conveniently.

2025-2026: Enhanced Predictive Analytics

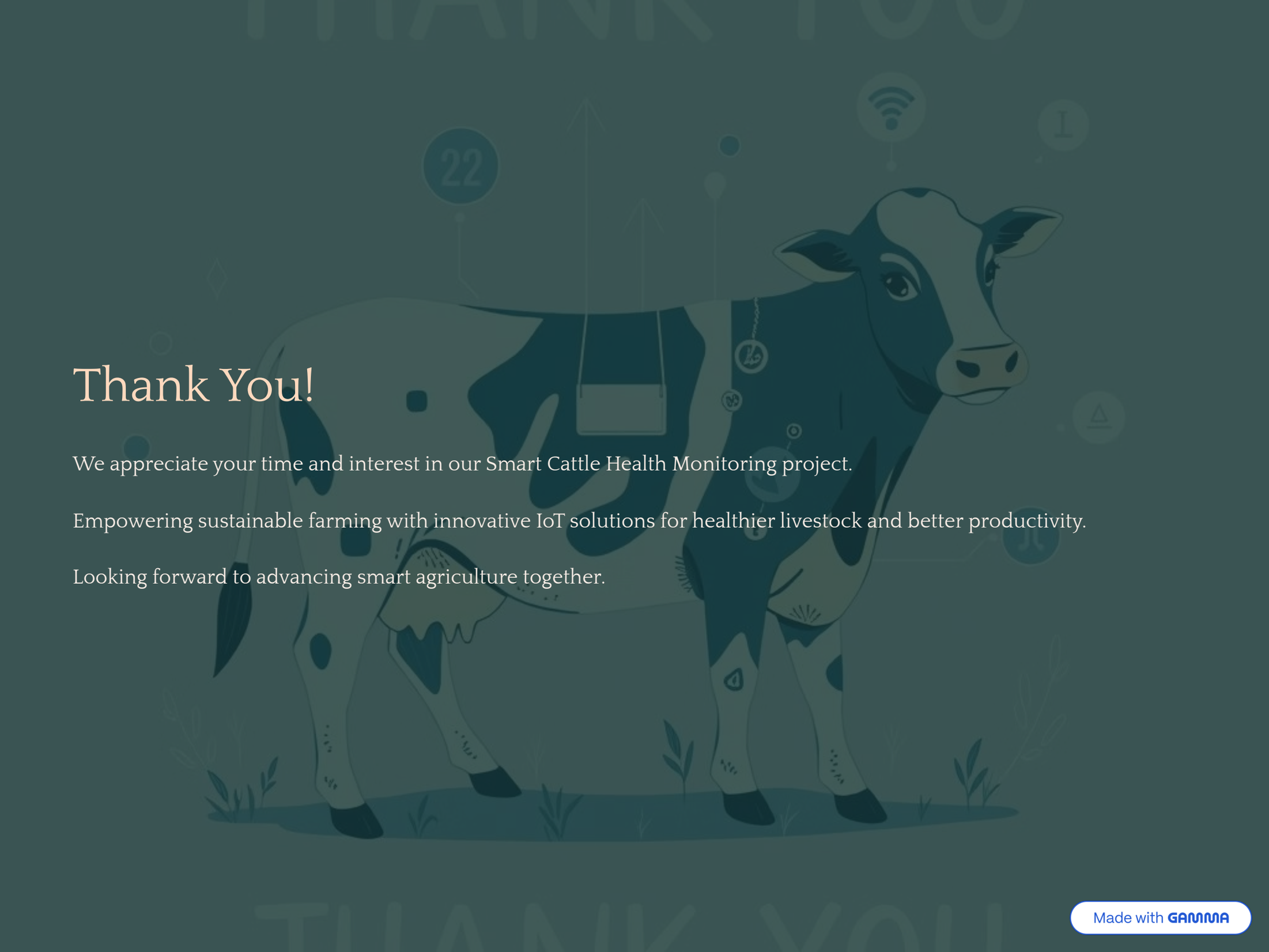
Deploy machine learning models to predict health issues and optimize cattle management decisions in real time.

2026: Multi-Sensor Integration

Expand the system to incorporate additional sensors for milk quality, soil health, and feed monitoring to provide a holistic farm management solution.

2026-2027: Automated Intervention Systems

Implement automated alerts and control systems for precise intervention such as targeted treatments and environmental adjustments.



Thank You!

We appreciate your time and interest in our Smart Cattle Health Monitoring project.

Empowering sustainable farming with innovative IoT solutions for healthier livestock and better productivity.

Looking forward to advancing smart agriculture together.