SMART LIVESTOCK HEALTH MONITORING SYSTEM

Abstract – Livestock health monitoring is a critical aspect of modern agriculture, directly impacting productivity and economic sustainability. This research presents a Smart Livestock Health Monitoring System using Internet of Things (IoT) technology to monitor cattle health parameters in real time. The system utilizes a Raspberry Pi 4B as the central processing unit, interfaced with a DHT11 sensor for temperature measurement, a heart rate sensor to classify cardiac activity into normal and abnormal ranges, and an accelerometer to analyse acceleration and compute rumination levels. The collected data is processed using Embedded C in the Thonny IDE and transmitted through a Wi-Fi module for remote analysis. The system is designed as a wearable neckband for continuous health monitoring. Heart rate variability is analysed to detect early signs of stress or disease, while the accelerometer provides insights into the cattle's movement patterns and activity levels. This integrated approach aims to deliver early warnings for health anomalies, reduce livestock mortality rates, and improve overall farm efficiency. The system measures various parameters such as body temperature, activity, heart rate and rumination and the collected data is sent as SMS through Twilio API.

Keywords: *IoT, livestock health monitoring, smart agriculture, Raspberry Pi 4B, Embedded C, heart rate classification, accelerometer analysis, temperature monitoring, wearable systems.*

I.INTRODUCTION

Livestock health plays a pivotal role in ensuring sustainable agricultural practices and meeting the growing global demand for animal-based products. Traditional methods of monitoring livestock health often rely on manual observation, which can be time-consuming, prone to errors, and ineffective in detecting early signs of health anomalies The advent of Internet of Things (IoT) technology offers transformative opportunities to enhance the efficiency and accuracy of livestock health management.

This paper introduces a Smart Livestock Management System that leverages IoT and embedded systems to provide real time monitoring of critical health parameters in cattle. The system employs Raspberry Pi 4B as the core processing unit integrated with the sensors such as DHT11 for temperature measurement, a heart rate sensor for cardiovascular health monitoring and an accelerometer to track movement and activity levels. These components are housed within a wearable neckband, enabling continuous data collection and transmission through a Wi-Fi module for remote access and analysis.

The proposed system is designed to classify heart rate into normal and abnormal ranges, calculate acceleration to assess physical activity, and monitor temperature for environmental and physiological assessments. By combining these parameters, the system provides an integrated approach to cattle health monitoring, enabling early detection of potential health issues and supporting proactive interventions.

This work aims to bridge the gap between traditional livestock management and modern IoT-enabled solutions, offering a scalable, cost-effective, and efficient approach to improving animal welfare, reducing mortality rates, and enhancing farm productivity. This paper details the system's design, implementation, and potential applications in smart agriculture.

The principal goal of this work is to create an IoT based livestock monitoring system to automatic and continuous measurement of the health of cattle in real time. This system also communicates with the farmer's mobile to inform the farmer with the real time information. This enables the farmers to monitor the cattle even in their absence and take immediate actions when there is an abnormality. This project also aims to improve the animal welfare by ensuring accurate health monitoring.

Structure of the paper: In order to synthesize current knowledge and place the project within the larger scientific context, Section 2 conducts a survey of the literature. The limitations of existing and current techniques are presented in Section 3. The suggested methodology is described in Section 4 which also describes the overview of the method used in Smart Livestock Health Monitoring system. The Section 5 of this paper emphasise on interpreting the results of the project's goals and discusses the main findings, outlines the implications and recommends the direction for further study. The Final section is the reference section that guarantees the studies and sources cited throughout it are properly credited.

II.LITERATURE REVIEW

In [1] the author proposed an IoT wearable device measures temperature, position activity and behaviour (Eating, sleeping, lameness). LoRa communication protocol is the IoT technology used for the communication of this information. The IoT wearable is the LoRa device which transmits the cattle's health information and the data is received by a LoRa gateway, which is the data hub of all received sensor data from the cattle. The collected data is then sent to cloud from the LoRa gateway. Data analytics is done on the cloud and a report is generated detailing the health of each cow in the farm. Based on this report the farmer can approach a vet, nutritionist, agronomist to get actionable intelligence to improve the cow's milk yield.

In [2] the author proposed a Wireless Sensor Based cattle health monitoring system, critical parameters affecting cattle health which includes body temperature, respiration, humidity, heart beat and rumination are continuously monitored. In this framework, Arduino UNO microcontroller is utilized to sense the various activities of animals like body temperature, respiration, humidity, heart beat and rumination. ESP8266 Wi-Fi module is used as transceiver. The i-Chart app is used to display the graph.

In [3] the main objective is to design a system that uses data gathering node and the mobile node and WSN to communicate between the nodes. The data collected by the mobile node is sent to the IoT cloud Platform. The sensors are connected to the

controller that acts as data gathering node and a RTC for TDMA The sensors are interfaced with the controller.

The Zigbee transceiver is connected using TDMA. The data communication functionalities of the mobile node are implemented using Raspberry Pi and ZigBee transceiver.

In [4] the author presented a new IoT based livestock monitoring system that is dedicated to the automated measurement of dairy cow health state in conventional loose-housing cowshed. There are three infrastructures, The Hub, WiFi access points and Routers. The hub is made by Raspberry Pi Zero Wwhich has BLE packets and uses RSSI algorithm. The data transmission is performed by serial communication GSM using REST communication Protocol. This system measures the acceleration of the cattle and hence its activity is monitored

In [5] this paper proposed an IoT based Cattle health and environment Health Monitoring system that uses Arduino Uno that receives data from the sensors such as Temperature sensor, Heart rate sensor and develops the content accordingly. The ESP8266 Wi-Fi module will transfer the data internet so that cattle can be monitored outside the farm. This system measures two of the major health parameters which are body temperature and heartbeat. The Arduino UNO microcontroller is used to gather data from the sensors. The body temperature and heartbeat of the cattle increases when it is affected by any disease. When the temperature increases, the GSM is used to notify the farmer with SMS.

In [6] the author proposes a health monitoring system to track individual animal movement as well as to monitor occurrence of diseases. Sensors are being mounted on the cattle to monitor the body temperature and heartbeat and pressure of each animal. The quality and security of milk and its results are completely related to provisions of sanitization and atmosphere. Herdsmen first implant sensors in the skin of cattle. The sensor can be installed in the ear tags of cattle's and inside the body i.e., boluses and also even on the collars. The mobile device, on the other hand communicates with the cloud via the internet system which allows the herdsmen gadgets to work effectively with the sensors. The herdsmen can then monitor the cow's health which will be highly user-friendly.

In [7] this paper proposed an IoT based tracking using cattle monitoring system that aims to compare the cattle's real health parameters to the typical reference safe values, enabling them to notice any decrease in their health. To construct such a gadget for real-time usage, an Arduino Uno, Arduino Nano, Xbee board, and several sensor devices for recording cow bodily conditions were employed. An Arduino Uno microcontroller was used to gather the sensor information. The body temperature and heart rate of cattle affected with a disease increase. The farmer gets alerted by SMS if the temperature increases. The climate on dairy farms has a significant influence on the animals' well-being. As a consequence, a SMS will be delivered to the producer when the temperature or moisture in the atmosphere increases.

III. LIMITATIONS OF EXSITING METHODOLOGY

Despite the advancements in IoT-based livestock health monitoring systems, several limitations persist in the existing

methodologies. The major limitation is that use of microcontroller without communication module will make system complex and bigger which results in inefficiency for the collar belt. Furthermore, various limitations of existing methodologies are For instance, systems utilizing LoRa communication ([1]) effectively transmit data over long distances but rely heavily on cloud analytics, which introduces delays and dependency on stable internet connectivity. Similarly, wearable devices integrating Arduino Uno and ESP8266 ([2]) face scalability challenges due to processing and memory constraints, while visualization tools like i-Chart lack advanced data analytics for comprehensive health assessments. The use of ZigBee with TDMA scheduling ([3]) limits application in large-scale farms due to its short-range communication and system rigidity. Moreover, BLE-based solutions employing Raspberry Pi Zero W ([4]) are unsuitable for large farms due to range limitations, while GSM modules increase power consumption and costs. Systems measuring only basic health parameters, such as body temperature and heart rate ([5]), fail to provide holistic health diagnostics. Implantable sensor systems ([6]) raise concerns about animal welfare and sensor longevity. Finally, many systems ([7]) lack integration of multiple health parameters, advanced analytics, or energy-efficient designs. These limitations underscore the need for a comprehensive, scalable, and real-time monitoring system, which the proposed Smart Livestock Management System aims to address effectively.

The proposed system addresses the limitations of existing livestock monitoring methodologies by integrating multiple health parameters into a unified framework. This approach combines temperature, heart rate, and activity monitoring into a single wearable device, enabling a holistic assessment of livestock health. To overcome challenges related to communication delays and cloud dependency, the system processes data locally before transmitting essential information via a reliable wireless communication module. This ensures real-time monitoring and reduces reliance on constant internet connectivity. The design also emphasizes scalability and energy efficiency, allowing for effective use in farms of varying sizes. By utilizing a comfortable wearable design, the system avoids the issues associated with implantable sensors and ensures long-term usability. Real-time alerts are generated to notify farmers and veterinarians of any abnormalities, enabling timely interventions. This comprehensive and efficient solution directly addresses the gaps in existing systems, offering a practical tool for improving livestock health management and farm productivity.

IV. PROPOSED METHODOLOGY

In this proposed system in order to monitor the health of the cattle three major components are used which are Heart rate sensor, temperature sensor and accelerometer in order to measure various health parameters like heart rate, temperature, activity of the cattle and rumination which varies when the cattle are affected by disease. This system employs raspberry pi 4 as the core processor integrated with the sensors for monitoring the cattle health and the inbuilt wifi module is used for the transmission of real time data as SMS through Online communication platform APIs such as Twilio.

Proposed architecture

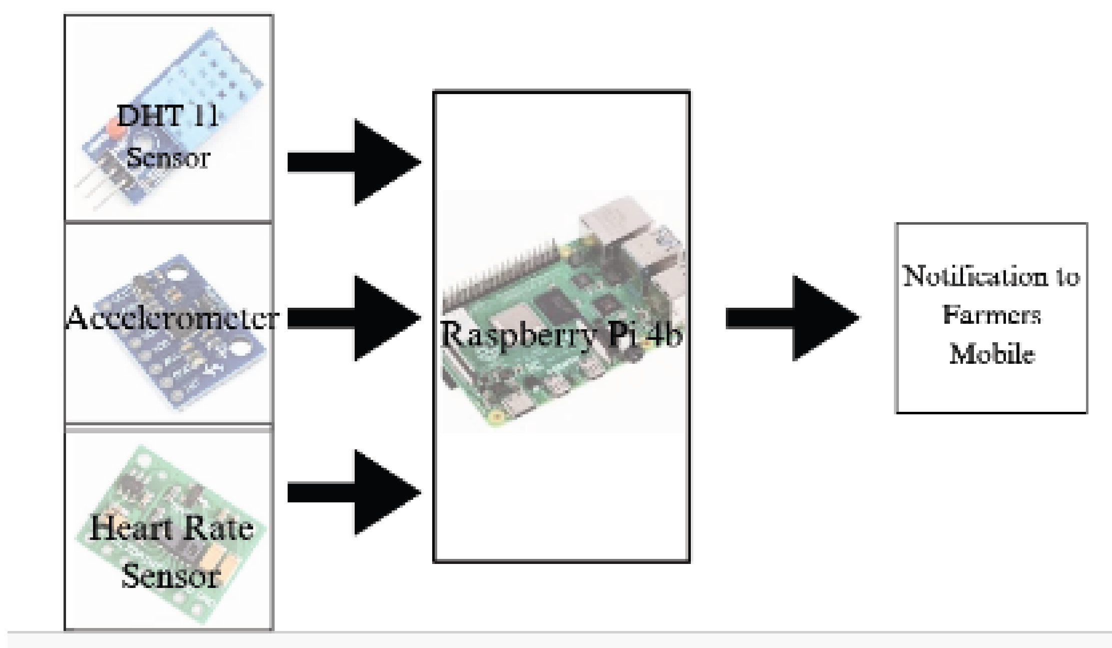

Fig.1: Proposed System Architecture

Module description:

Raspberry Pi 4B: The Raspberry Pi 4B acts as the central processing unit of the system. It is responsible for interfacing with the sensors, processing the collected data, and managing communication with external devices or servers. Its quad-core processor and ample memory ensure smooth operation even under continuous data acquisition. Additionally, its support for multiple GPIO pins enables seamless integration with various sensors. The onboard Ethernet and Wi-Fi capabilities provide flexible connectivity options for remote monitoring. In this proposed system it acts as the core processing unit that collects and interprets the data from the sensors and communicate to the users through Wi-Fi module.

DHT11 Sensor: The DHT11 sensor measures environmental temperature and humidity around the cattle. This data helps monitor the comfort level of livestock and detect environmental stressors. The sensor provides a digital output, making it easy to integrate with the Raspberry Pi. Its low power consumption makes it suitable for continuous operation in remote areas. The compact design of the DHT11 allows for easy installation in different farm setups. This sensor is used to identify the body temperature of the cattle by placing it on the neck of the cattle.

Heart Rate Sensor: The MAX30102 is an advanced optical sensor designed to measure heart rate and blood oxygen levels. It uses infrared and red LEDs along with a photo detector to detect pulse rates. This sensor is ideal for real-time cattle heart rate monitoring due to its high accuracy and ability to operate in varying lighting conditions. It outputs digital signals, which are directly processed by the Raspberry Pi. The MAX30102 also features an integrated ambient light cancellation mechanism, ensuring reliable readings in outdoor environments. Its compact and lightweight design facilitates non-intrusive attachment to livestock. In this livestock health monitoring system this MAX30102 digital sensor is used to detect the heart rate of the cattle.

Accelerometer: The MPU6050 is a six-axis motion tracking device that combines a 3-axis gyroscope and a 3-axis accelerometer. It is used in this system to monitor cattle movement and detect activity patterns. The accelerometer data is analysed to derive metrics such as rumination time and resting behaviour, which are crucial for assessing livestock well-being. The sensor communicates with the Raspberry Pi via the I2C protocol, ensuring efficient data transfer. Additionally, the MPU6050's motion detection capabilities help identify

abnormal behaviour, such as restlessness or prolonged inactivity. In the proposed system MPU6050 is used to measure the activity of the cattle and rumination of the cattle.

The various type of sensors such as DHT11, Heart rate sensor and accelerometer are being fitted to the cattle at proper positions to measure the parameters properly. The table 1,2 and 3 explains the behaviour of cattle health based on the variation of temperature and acceleration.

	Behaviour	Value

Temperature sensor	Cold	35.5°C to 38.5°C
	Normal	38.5°C to 39.5°C
	Low Fever	39.5°C to 40.5°C
	Middle Fever	40.5°C to 41.5°C
	High Fever	Above 41.5°C

Table 1. Behaviour due to varying temperature

	Behaviour	X	Y	Z
Accele-rometer	Standing	Constant	Constant	Constant
	Sitting	Constant	Constant	Slight change
	Walking	Varies	Varies	Varies
	Lying	Near Constant	Near Constant	Constant

Table 2. Behaviour based on acceleration

	Behaviour	X	Y	Z
Rumina Tion	Normal	Periodic	Periodic	Constant
	Slower	Minimal Periodic	Minimal Periodic	Constant
	Faster	Frequent Periodic	Frequent Periodic	Constant
	Interrupted	Irregular	Irregular	Varies
	No activity	Constant	Constant	Constant

Table 3. Behaviour based on rumination

Circuit Explanation

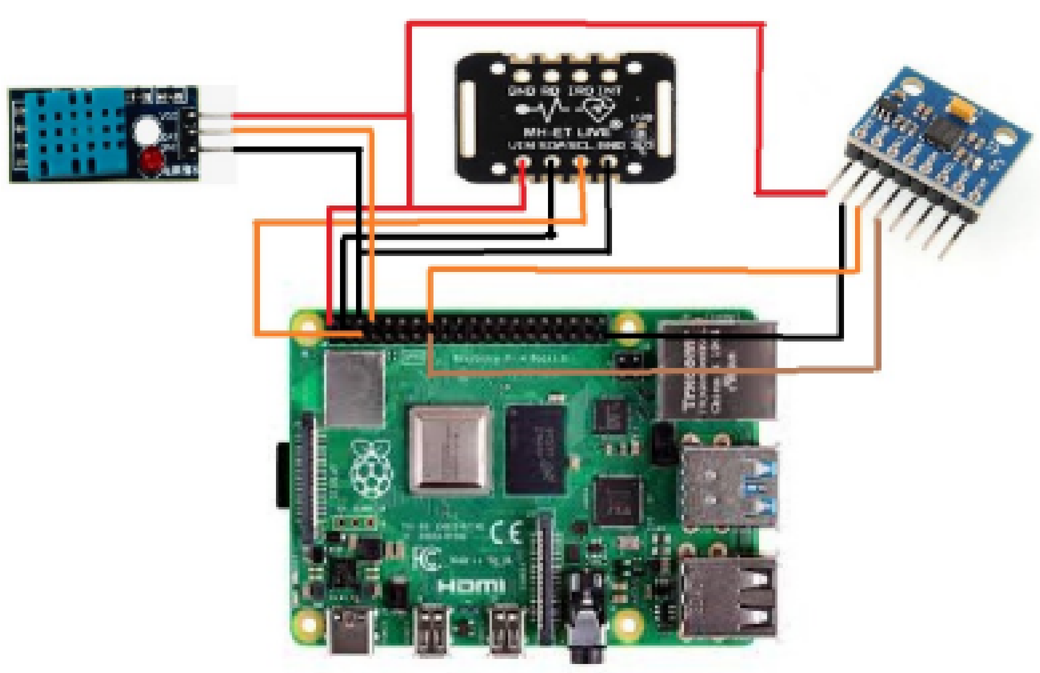

Fig 2. Schematic Diagram

The Raspberry Pi 4B is the core processing unit of this system the various sensors such as DHT11, MAX30102 (heart rate sensor) and MPU6050 sensor(accelerometer) is used.

The DHT11 sensor is a 3 Pin digital sensor. The digital data pin is connected to the GPIO pin xx of the Raspberry pi 4 and the VCC pin is connected to the 3.3V pin of Raspberry Pi 4 and Ground pin is connected to ground.

MPU6050 is a 6 Pin digital accelerometer that communicates with the core processor using I2C protocol that uses SDA (Serial Data Line) and SCL (Serial Clock Line) pins. The VCC Pin is connected to 3.3V on the Raspberry pi. The Ground pin is connected to the Ground, The SCL pin is connected to GPIO 3 (which is I2C SCL pin on raspberry pi) and SDA pin is connected to GPIO 2(which is I2C SDA pin on raspberry pi).

MAX30102 is a heart rate sensor whose VCC pin is connected to 3.3V pin on raspberry pi and ground pin is connected to the ground, It is also a digital sensor that communicates with the core processor using I2C protocol. The SCL pin is connected to GPIO 23 (which is I2C SCL pin on raspberry pi) and SDA pin is connected to GPIO 24(which is I2C SDA pin on raspberry pi).

Flowchart

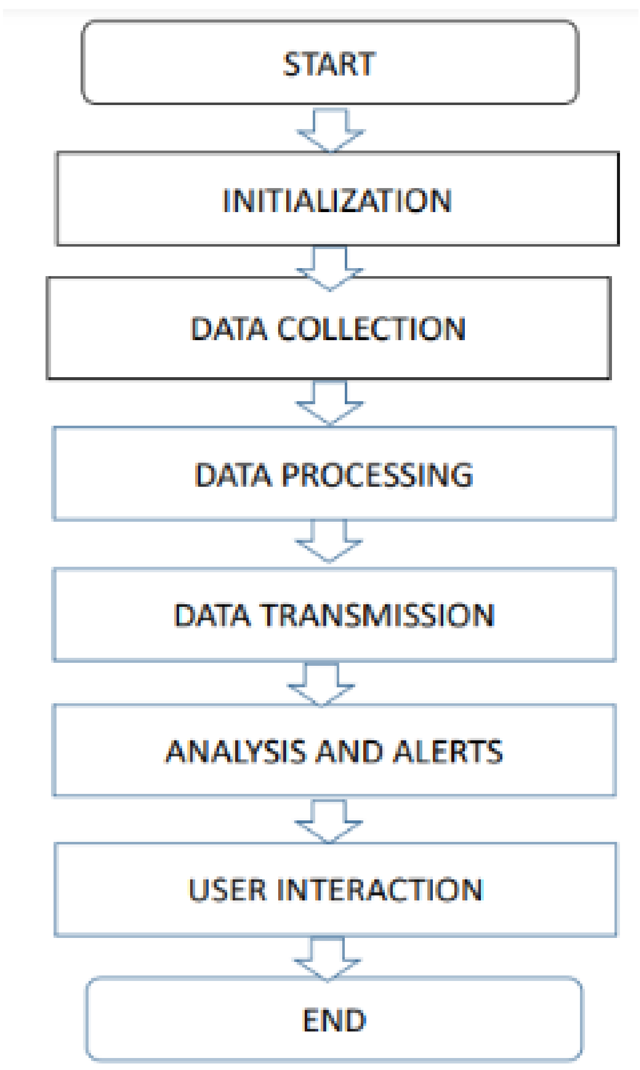

Fig 3. Flowchart of methodology

Algorithm

Step 1: Initialise the system that is configure GPIO pins and I2C communication. Initialize sensors: DHT11 (temperature), MPU6050 (accelerometer), and heart rate sensor and Set up Twilio API with account credentials for SMS notifications.

Step 2: Collect the real time data from Heart rate sensor. DHT11 for temperature readings. MPU6050 for X, Y, Z acceleration values.

Step 3: Process the data collected from the sensors, and classify the data based on normality and abnormality for temperature sensor and heart rate sensor. Using the accelerometer detect the activity and rumination

Step 4: Send Alerts with the data processed as SMS alert via Twilio API to the farmer or veterinarian.

Step 5: Delay for Next Iteration.

Pseudo code

```
START       // Step 1: System Initialization

Initialize and Setup DHT11, Heart Rate Sensor, Accelerometer

Initialize Raspberry Pi 4B

Initialize GPIO and I2C

Setup Twilio API with account credentials

Initialize variables for signal data (heart rate)

WHILE (System is Active)       // Step 2: Data Collection

    temperature = ReadTemperature(DHT11)

    heart_rate = ReadHeartRateSensor()

    acceleration = ReadAccelerometer()

     rumination = ReadRumination()

    // Step 3: Data Processing

    IF (heart_rate < MIN_THRESHOLD OR heart_rate >
MAX_THRESHOLD)

      status_heart = "Abnormal"

    ELSE

      status_heart = "Normal"

    IF (AnalyzeAcceleration(acceleration) == "High")

      activity_status = "Abnormal Activity Detected"

    ELSE

      activity_status = "Normal Activity"
```

Calculate rumination frequency and state (Normal/Abnormal) // Step 4: Data Transmission

SendDataToCloud(temperature, heart_rate, acceleration)

IF (status_heart == "Abnormal" OR activity_status == "Abnormal Activity Detected" OR temperature > MAX_TEMP) // Step 5: Alerts and Notifications

SendAlert("Abnormal condition detected via Twilio API")

END WHILE

END

V RESULTS AND DISCUSSION

Experimental Setup:

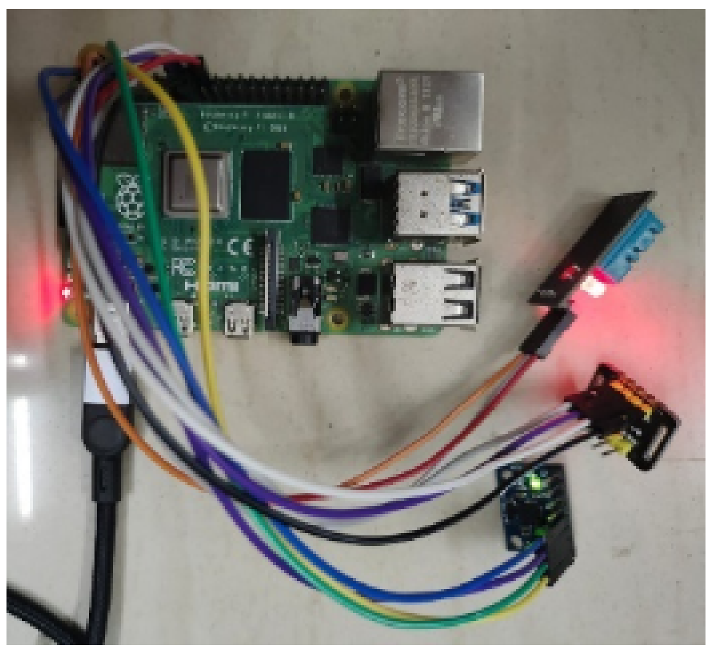

Fig 4. Experimental setup

The Raspberry Pi is powered by external power supply and the sensors connected to the GPIO pins of the raspberry pi. Then the sensors are initialised. The raspberry pi is trained such that the data collected from the sensors is processed to identify various health parameters like body temperature, heart rate, activity of the cattle and rumination. The processed information is transmitted to the farmer's mobile as SMS via Twilio API. The system is trained to detect for every hour.

Performance Analysis

The analysis has been given below.

Time	Temp	Heart rate	Activity	Rumination
8.00	37 C	75 BPM	Walking	Normal
9.00	37 C	73 BPM	Standing	Normal
10.00	37.5 C	72 BPM	Standing	Normal
11.00	37.5 C	72 BPM	Standing	Normal
12.00	37.5 C	74 BPM	Standing	Normal
13.00	38 C	75 BPM	Standing	Normal

Table 4 Performance Analysis

Graphical Interpretation

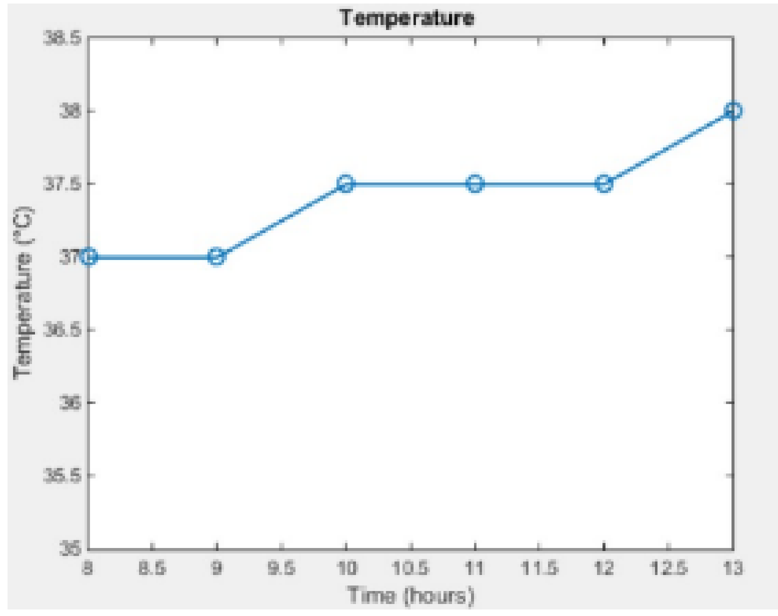

Fig 5 Graphical analysis of temperature

The graph in Fig 5illustrates the heart rate variation of livestock (in bpm) over a 5-hour period (8 to 13 hours), recorded using a pulse oximeter integrated into the proposed IoT-based smart livestock health monitoring system. The gradual increase in heart rate from 72 bpm to 79 bpm reflects physiological or environmental influences, such as activity levels or stress. By establishing species-specific thresholds, the system can identify anomalies in real time, triggering alerts via the Twilio API for timely intervention. Correlating this data with accelerometer-based activity tracking and environmental parameters like temperature (from the DHT11 sensor) provides comprehensive health insights, enabling early detection of issues like heat stress, tachycardia, or bradycardia. This demonstrates the system's capability to enhance livestock management through accurate, real-time monitoring and proactive health care.

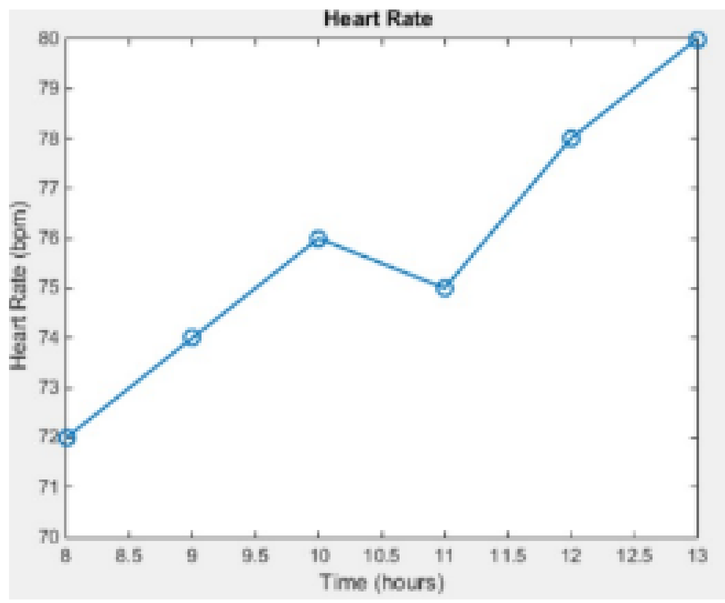

Fig 6 Graphical analysis of Heartrate

The graph in *Figure X* represents the temperature variation (in ° C) of livestock over a 5-hour period (8 to 13 hours), measured using the DHT11 sensor integrated into the proposed IoT-based smart livestock health monitoring system. The gradual increase in temperature from 37° C to 38° C could be attributed to normal metabolic processes, environmental heat, or stress factors. This data is critical for monitoring livestock health, as deviations from the species-specific normal temperature range might indicate illness, such as fever or hypothermia. Combined with other health metrics like heart rate and activity levels, the system can provide a comprehensive analysis of the animal's condition. Anomalies in temperature trends can trigger real-time alerts via the Twilio API, enabling prompt action. This capability ensures early detection of heat stress or other health issues, enhancing livestock welfare. The consistent temperature readings validate the sensor's reliability and the system's effectiveness in real-time health tracking

Discussions

The Smart Livestock Health Monitoring System represents a significant advancement over traditional livestock health monitoring methods. Traditional systems rely heavily on manual observation and periodic physical examinations to assess the health of animals. These methods are labour-intensive and often delay the detection of diseases or health issues until visible symptoms appear, which can be too late for effective intervention. Additionally, they lack the ability to provide consistent, round-the-clock monitoring, leaving significant gaps in the data needed to understand the well-being of livestock comprehensively.

In contrast, the Smart Livestock Health Monitoring System, leveraging a Raspberry Pi 4 alongside an accelerometer, temperature sensor, and heart rate sensor, offers real-time tracking of critical health parameters such as rumination, physical activity, body temperature, and heart rate. This automation allows for continuous monitoring, providing caretakers with instant notifications about abnormal patterns. For example, an increase in body temperature could indicate fever, while irregular heart rate or reduced activity may signal stress or illness. Early detection of such signs enables timely interventions, reducing the risk of disease spread and improving the chances of recovery, thereby enhancing overall herd health and productivity.

Another advantage of this system is its efficiency in labour management. By automating data collection and analysis, it significantly reduces the time and effort required for manual health checks. This allows farmers to focus on other aspects of livestock management while the system ensures consistent health monitoring. Moreover, the system's ability to collect and store data over time facilitates trend analysis and predictive insights, enabling more informed decisions regarding the management of animal health and farm operations.

However, the system is not without its limitations. Sensor accuracy and precision are critical factors that can impact the reliability of the measurements. For instance, environmental conditions such as extreme temperatures or humidity could affect sensor performance, leading to incorrect readings. The placement and calibration of sensors also play a crucial role in

ensuring data accuracy. Additionally, the complexity of integrating various sensors and maintaining the system can pose challenges, particularly for small-scale farmers with limited technical expertise. Dependence on electronic components also raises concerns about system robustness and the need for regular maintenance.

Despite these limitations, the Smart Livestock Health Monitoring System offers a transformative approach to livestock management, combining technology and automation to address the inefficiencies of traditional methods while paving the way for more sustainable and proactive animal care.

Comparison of existing methodologies

S. No	Features	Proposed System	[10]	[8]	[5]
1	Raspberry Pi 4B	✓	X	X	X
2	Arduino UNO	X	X	✓	✓
3	Node MCU	X	✓	✓	✓
4	DHT sensor	✓	✓	✓	✓
5	Heart rate senso	✓	✓	✓	✓
6	Accelerometer	✓	X	X	✓
7	GSM module	X	X	✓	✓
8	Twilio API	✓	X	X	X

Output Received

After connecting all the sensors on the cattle's body, the real time values from the sensors is sent as a SMS to the farmer's mobile through the online communication API such as Twilio.

The notification describes whether the temperature and heart rate is normal or abnormal and activity of the cattle is also specified in the message sent. The system is designed such that the message is sent every 60 minutes.

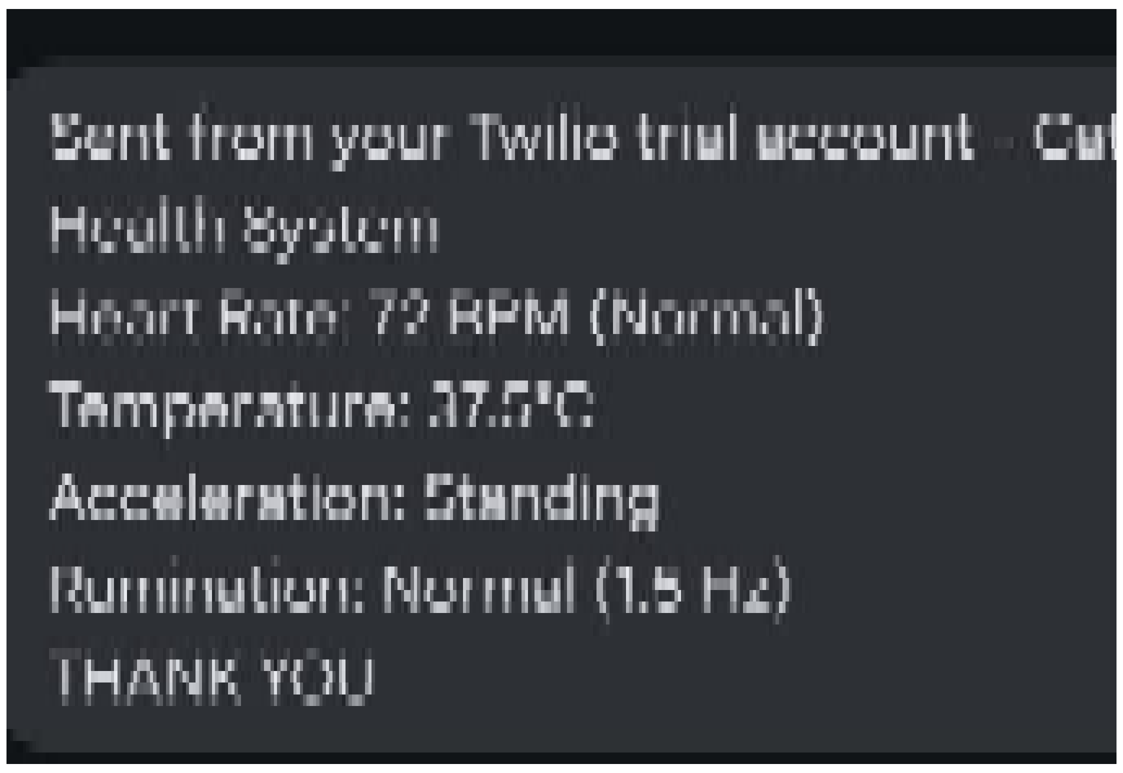

Fig.6 Message received after execution.

Conclusions and future scope

The Smart Livestock Health Monitoring System represents a significant innovation in modern agriculture, offering a comprehensive solution for monitoring livestock health. By accurately measuring key parameters such as heart rate, body temperature, activity acceleration, and rumination, the system provides real-time data that is essential for maintaining animal well-being. Performance evaluations have confirmed the system's reliability and precision, making it an invaluable tool for farmers.

This system introduces a proactive approach to livestock management. Through continuous monitoring, it enables the early detection of health anomalies, allowing for timely interventions that mitigate risks and reduce the likelihood of disease outbreaks. This capability not only ensures better animal health but also reduces mortality rates, minimizes veterinary costs, and enhances overall farm productivity. By generating actionable insights, the system empowers farmers to make informed decisions, optimizing the use of resources and improving operational efficiency.

The potential for future advancements in the Smart Livestock Health Monitoring System is vast. Incorporating predictive analytics powered by machine learning could enable the prediction and prevention of health issues before they occur. Expanding compatibility with a broader range of IoT devices and sensors can enhance the system's versatility, while the integration of remote monitoring features would cater to the needs of large-scale farming operations. Additionally, adapting the system to support various species of livestock would make it more universally applicable.

In conclusion, the Smart Livestock Health Monitoring System is a transformative step forward in livestock management. By leveraging advanced technology for real-time monitoring and early intervention, it fosters healthier livestock, reduces health-related risks, and improves farm productivity. This system not only supports sustainable farming practices but also positions the agricultural industry for a future of efficiency and resilience, ensuring better outcomes for farmers and animals alike.

The future scope of the smart livestock health monitoring system using Raspberry Pi 4B, heart rate sensor, accelerometer, DHT11, and Twilio platform offers significant potential for advancing precision livestock farming. By integrating real-time monitoring capabilities with remote communication, the system can be expanded to include additional sensors for monitoring other vital signs like respiration rate, temperature, and hydration levels. With the increasing integration of machine learning, predictive analytics can be applied to foresee health issues, optimize herd management, and enhance overall animal welfare. Future developments could also involve cloud-based data storage, integration with other IoT devices, and enhanced data analytics for better decision-making, ultimately leading to automated health interventions, early disease detection, and improved productivity in livestock farming.

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