IOT and AI based smart cattle health monitoring

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Abstract

Cattle health monitoring is essential in the modern world, because of the high demand for dairy products. Regular monitoring is essential to extend the lifecycle of cattle and maintain the quality of dairy products. Unfortunately, Observing the health of cattle regularly is difficult in large farms where workers do not have enough time to do so. This paper described IoT devices such as skin temperature, heart rate, and motion sensor. Using this device, you can monitor cattle’s heart rate, activity level, heat stress, the surrounding temperature, and sleep tracking. The IoT system is integrated with the cloud. a machine learning algorithm predicts the health status of cattle based on the sensor’s real-time data, observing the real-time health status will alert the user if cattle suffer from a health issue, and a mobile app is developed to observe data visualization. Cattle health monitoring systems are designed to monitor the health of individual cattle and quickly diagnose and treat sick cattle.

Keywords: Cattle health monitoring; IoT; Cloud System; Mobile app; Machine Learning

Introduction

Animal husbandry refers to the management and care of domestic animals, such as cattle, pigs, chickens, and sheep, for the motive of producing food, fiber, and other products. Animal husbandry involves a wide range of activities, including breeding, feeding, housing, and healthcare, all aimed at improving the productivity, health, and welfare of the animals.

The goals of animal husbandry are to increase the quantity and quality of animal products, such as milk, eggs, and wool, while also ensuring the welfare and health of the animals. Animal husbandry practices may vary depending on the species of animal and the specific purpose for which it is being increased, such as for dairy production, etc. Dairy cattle are the most efficient of all farm livestock to provide protein and it is essential to keep dairy cows in good condition in order to ensure that the dairy products, such as milk, are of high quality.

The health of cattle is one of the most significant aspects that impact dairy cow productivity. Here are some key aspects of healthcare for dairy cattle: 1. Nutrition: Providing a balanced and sufficient diet is critical for the health of dairy cattle. The diet should include a mix of roughage and concentrate, along with clean and fresh water. A nutritionist can help to formulate a balanced diet based on the cow's nutritional needs. 2. Housing: Dairy cattle should be housed in a clean, dry, and well-ventilated environment. Overcrowding and poor ventilation can lead to respiratory diseases, while damp and dirty conditions can cause foot and udder problems. 3. Vaccinations: vaccines are available for a number of diseases that affect dairy cattle, including bovine viral diarrhea, infectious bovine rhinotracheitis, and leptospirosis. 4. Parasite control: Parasites can cause a range of health problems in dairy cattle, including weight loss, anemia, and decreased milk production. 5. Reproductive management: Proper reproductive management is essential for maintaining the fertility of dairy cattle. This may include artificial insemination, pregnancy diagnosis, and management of calving. 6. Regular health checks: Regular health examinations can help to recognize health problems early before they become more serious.

By monitoring the health of cattle, farmers can take preventive measures such as administering vaccines, adjusting feed and nutrition, and providing appropriate treatments in a timely manner. Cattle health monitoring is important for several reasons. First, it helps to ensure the welfare of the animals by identifying and treating any health issues as quickly as possible. Second, it assists in preventing diseases and parasites among animals, which can be costly and harmful to both the animals and the farmers who care for them.

IoT devices are utilized to monitor the well-being of cattle, benefits of using IoT devices for cattle health monitoring include improved animal welfare, reduced healthcare costs, and increased productivity.

There are several existing cattle health monitoring systems that have been developed to monitor the health of cattle. “LiveCare” a IoT-based framework was developed to automatically monitor the health of cows in a large cow farm. It tracks the health of cows by using IoT devices such as Temperature sensor, Accelerometers, heart rate sensor, Saliva sensor, Gas sensor, and Microphone, to monitor on a daily basis, their research Cow Disease Prediction (CDP) algorithm, which is an unsupervised multi- class classifier that serves as the LiveCare framework’s central component. The CDP algorithm gets 100% and κ-means 98% accuracy, CDP algorithm is used to predict more cow diseases accurately such as certain health issues like fever, cyst, mastitis, pneumonia, black quarter, foot and mouth disease, etc (Chatterjee 2021). A custom-designed multi-sensor board was developed to record several physiological parameters including skin temperature, heart rate, and rumination w.r.t surrounding temperature, humidity, and a camera for image analysis to identify different behavioral patterns, where data analytics will be performed using machine learning (ML) models to detect sick animals (Chaudhry, 2020). Nootyaskool, (2020) developed a model where Data of walking and scraping of the cow was collected on the server. The purpose of the device was to monitor cow behaviors and it can predict illness. Another system employed data collection from temperature sensors, heart rate sensors, and inertial measurement units mounted on the neck of a dairy cow. The collected data is stored and classified using machine learning to produce normal, less normal, and abnormal health classification outputs (Pratama et al, 2019). “MOOnitor” is an integration of a temperature sensor, GPS module, and a 3-axis accelerometer, transmission of data to an IoT server, After acquiring the necessary sensory information, the most significant features were strategically extracted for enhanced data interpretation. ML is used specifically on a 3-axis accelerometer. Thereafter, optimally tuned (XGBoost) and Random Forests classifiers were implemented to classify activities like ‘standing’, ‘lying’, ‘standing and ruminating’, ‘lying and ruminating’, ‘walking’, and ‘walking and grazing’. XGBoost accuracy ~97%, on the other hand, an optimally tuned Random-Forest classifier demonstrated an accuracy of 94.21%. (Mandal, 2020). A combined monitoring and detection system into one application utilizing the IoT and Intelligent System technology was also developed. The monitoring system processes the temperature and heart rate data of cows from the sensor, then gives results of a cow's health condition, normal or abnormal. their experiment on Intelligent System used Decision Tree with 90% accuracy (Faruq, 2019)

Further, to prolong the lifecycle of cattle and sustain the quality of dairy products, regular monitoring of cattle’ health is essential. But day-to-day monitoring of Cattle’s health is difficult, specifically in large farms where workers do not have sufficient time to observe the animals’ health physically. This paper investigates the existing technologies and provide a comparison of the features offered by these systems and their limitations. This is the main motivation behind this paper to analyze the different research methods concerning Cattle health monitoring and present a solution that will monitor the cattle in real-time with the help of IoT along with ML and cloud-based technology and bring some new features. This paper presents the following IoT sensors that can be considered to analyze cattle's health,1. skin temperature sensor, 2. heart rate sensor, and 3. motion sensor. It may help to provide valuable insights such as heart rate, activity monitoring, heat stress, the surrounding temperature, and sleep tracking. And we also aimed to develop a mobile app to observe data visualization.

Material And Methods

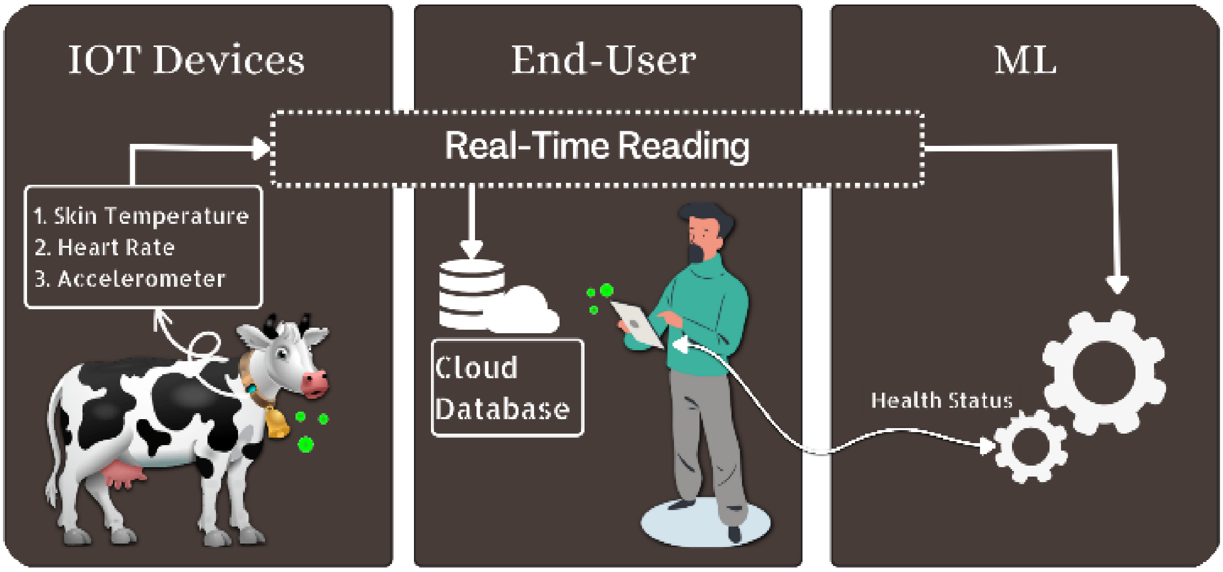

Fig 1. Graphical representation of cattle health monitoring System

Fig. 1 shows, our experiment's proposed system included both monitoring and intelligent systems, a monitoring system used IoT sensors, and intelligent systems used Machine learning.

1. Monitoring System

Fig. 1 shows, the first section is about IoT devices, IoT devices such as skin temperature, heart rate, and Accelerometer, these devices allow to monitor the health of cows by these five parameters. 1. heart rate, 2. activity level, 3. heat stress, 4. surrounding temperature, and 5. sleep tracking.

1.1. Monitor Heartbeats:

Heart rate is measured by Pulse-Sensor, and the reading from a pulse sensor is provided as digital data in "BPM" format. Normally the heartbeat range in a healthy cow is 48-84 beats per minute (M. S. Farooq, 2022)

1.2. Monitor Activity level:

Activity level is measured by (Mpu6050) sensor and the data from a Mpu6050 sensor is provided as digital data in the "X", "Y", and "Z" axis, and based on this three-axis provide status such as Standing or Laying as shown in Table-1.

1.3. Monitor Heat stress:

Heat stress is measured by (Mlx90614) sensor and the reading from an Mlx90614 sensor is provided as digital data in the degree Celsius. as well as this sensor provides humidity around cattle.

1.4. Monitor Sleep tracking:

Sleep tracking is tracked with the support of a Pulse-Sensor along with Activity level.

2. Mobile app and Firebase Cloud

The second section is about the end-user, end-user can access the mobile app for data visualization. Mobile apps are often used for IoT (Internet of Things) devices Because they offer a simple user interface for managing and interacting with IoT devices. Mobile app retrieved data from real-time firebase cloud. firebase Realtime Database, easy to create and manage IoT applications that require real-time data synchronization,

3. Machine learning

The third section is machine learning, machine learning is used in "AI HealthCare" i.e. cattle's overall health, and "AI HealthCare" is to predict cattle's overall health status. The status is displayed on the mobile app.

To predict "AI HealthCare" i.e. cattle's overall health, here the model is trained with both Random Forest and XGBoost classification algorithm, classification is used to predict health status such as healthy or unhealthy, and both predict with 100% accuracy thus the model is overfitting to avoid overfitting cross-validation (k-fold-10) is used, now the accuracy of random forest is 96% and XGBoost is 97%.

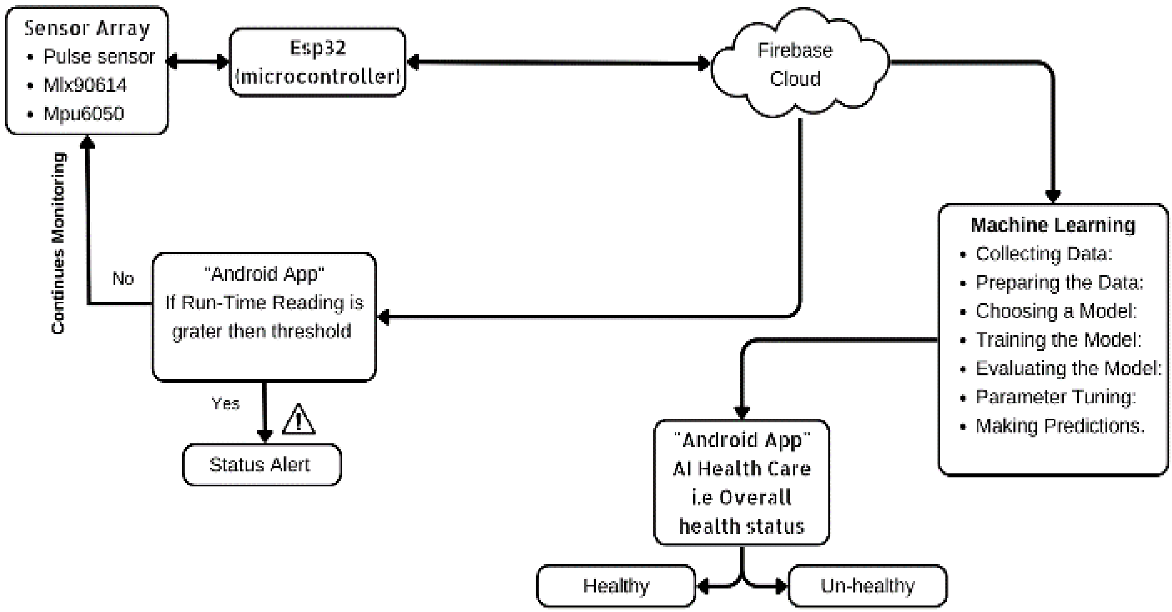

Fig 2. Block Diagram

Table-1

Sr No.	Status of Activity Monitoring	Definition
1	Standing	The cattle stand on its four feet with its head up or down.
2	Lying	The cattle sit on the surface with its head up or down.

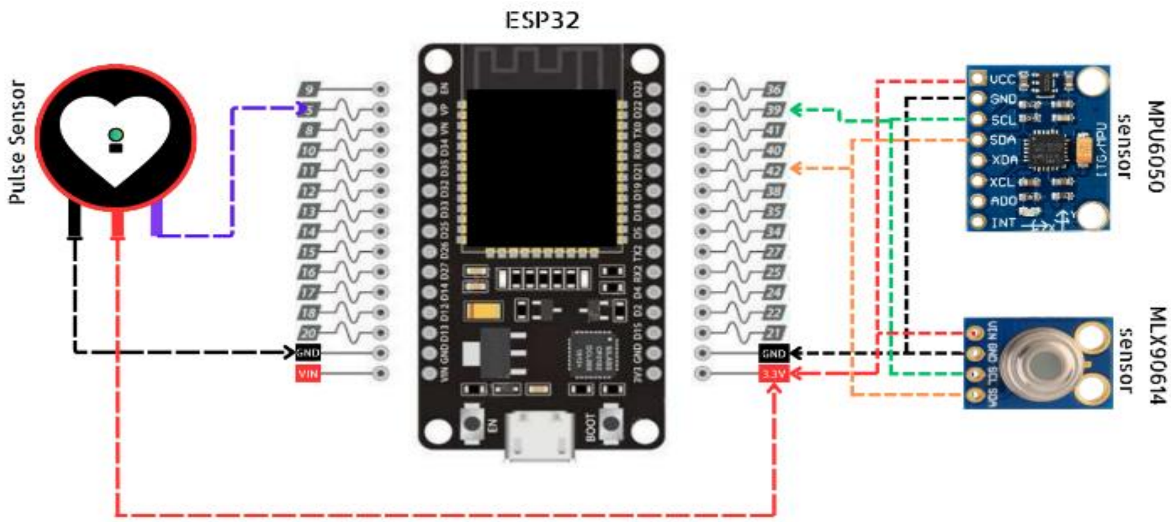

Fig 3. Circuit Diagram

ESP32

The low-cost, low-power ESP32 microcontrollers have dual-mode Bluetooth and built-in Wi-Fi. To enable Wi-Fi and Bluetooth functionality, ESP32 can link to other devices via its SPI or I2C interfaces.
This project has the ability to function I2C protocol, as a master or a slave. a controller act as a server and sensors acts as a slave. The I2C pins by default are SDA: SDA (GPIO 21 by default), SCL: SCL (GPIO 22 by default),

MLX90614

The MLX90614 is a powerful infrared sensor. Because it uses I2C communication, it can be attached to microcontrollers like the ES32 via I2C pins. according to Fig. 3. The SDA, SCL, GND, and VIN pins are the I2C pins, respectively. Factory calibrated in wide temperature range: -40 to 125.C for sensor temperature and -70 to 380.C for object temperature. High accuracy of 0.5.C over wide temperature range (0..+50.C for both Ta and To).
The actual readings of body temperature were taken by code: int tempe = mlx.readObjectTempC();
and VCC: often 3.3V or 5V.

MPU6050

The 3-Axis gyroscope and 3-Axis accelerometer are both included on the MPU6050 chip. The X, Y, and Z axis rotational velocity and rate of change of angular position are measured by the gyroscope.
This sensor uses I2C communication and therefore it is connected to microcontrollers like ES32 through the I2C pins. The I2C pins are SDA, SCL, GND, and VIN pins respectively.

Pulse Sensor

Pulse Sensor is the change in the volume of a blood vessel that occurs when the heart pumps blood and a detector that monitors this volume change.
As shown in Fig.3. pulse sensor is connected to ESP32 via Pin-1 (GND), Pin-2 (VCC), and Pin-3 (Signal).
The actual readings of pulse rate were taken by code:

- int Pulse Sensor Purple Pin = 36;
- int percentage = (Pulse Sensor Purple Pin/4096) * 100;
- Note: 4096-channel analog-digital converter for pulse height analysis.

Experiment Setup and Result

Fig 4. Smart Collar for Cattle

As shown in Fig 4, the whole model is created over a period of six months. finally, the smart collar with the reflective belt is ready for testing.

Fig 5. Experiments on cattle

As shown in Fig 5, two separate dairy cows were used to test this smart collar at the "Sheth Nathulal Trust Gaushala" in "Mumbai". Two-day trial on cattle was conducted in the afternoon and evening each day.

```
[1104] a = predict_cattle_health(model_cattle=rfr_clf,heart_rate=60, heat_stress=20, activity='walking')
       print("health of cattle:", a)

       health of cattle: ['healthy']

[1105] a  = predict_cattle_health(model_cattle=rfr_clf,heart_rate=40, heat_stress=15, activity='laying')
       print("health of cattle:", a)

       health of cattle: ['unhealthy']

[1308] a = predict_cattle_health(model_cattle=rfr_clf,heart_rate=75, heat_stress=30, activity='standing')
       print("health of cattle:", a)

       health of cattle: ['healthy']

[1309] a  = predict_cattle_health(model_cattle=rfr_clf,heart_rate=65, heat_stress=40, activity='laying')
       print("health of cattle:", a)

       health of cattle: ['unhealthy']
```

Fig 6. Machine learning prediction

Fig. 6. Shows Machine Learning model predicts the result successfully, API was written to predict the model on the mobile app as shown in Fig. 7.

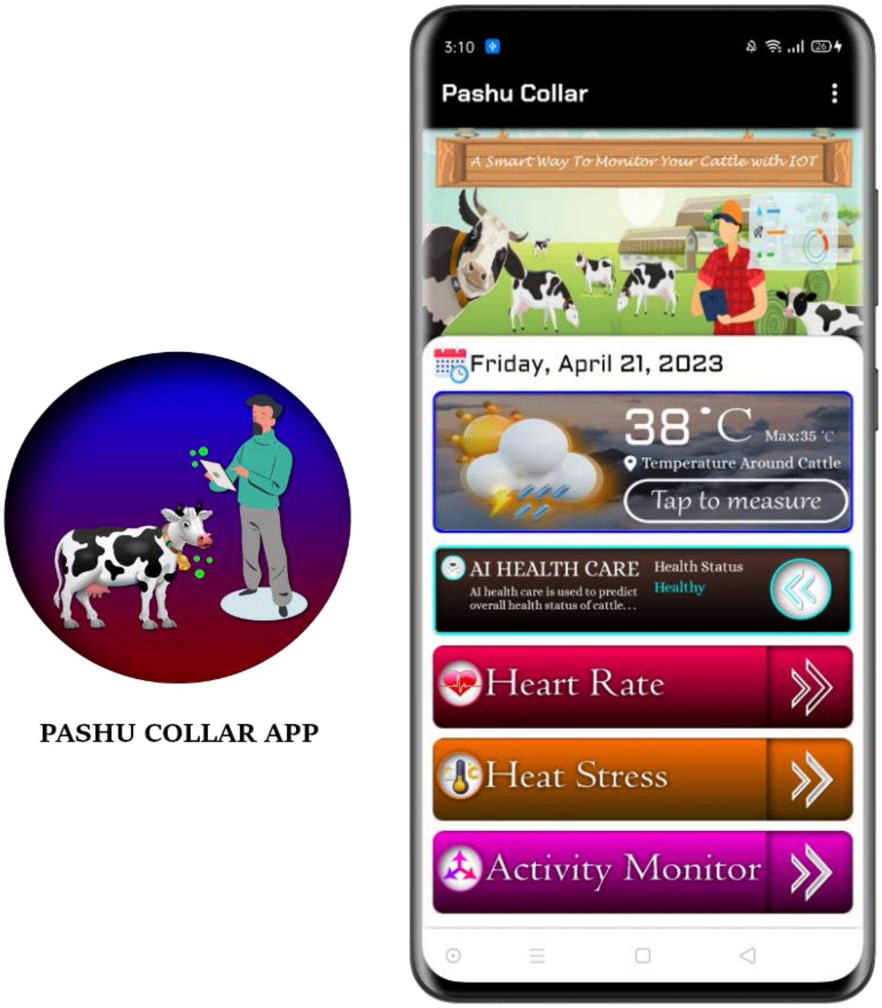

Fig 7. Prediction of health on Pashu Collar (Mobile App)

------The Experiment was held during the Summer (March) of 2023 in the Mumbai region in India, where the temperature in day time approx. (35.C to 39.C), and in the evening temperature goes down approx. (20.C to 25.C) (Accuweather.com, 2023).

As shown in Fig 3, Data collected during the experiment:

Heart rate: 70 BMP in 1st cattle and 73 BMP in 2nd cattle.

Heat Stress: 36.C to 39.C range where the status got as an “Unsafe”, in both cattle test scenario.

Activity Monitor: 1st cattle status got as laying and 2nd cattle status got as standing position and in both cattle test scenario sleeping status is “not sleeping”.

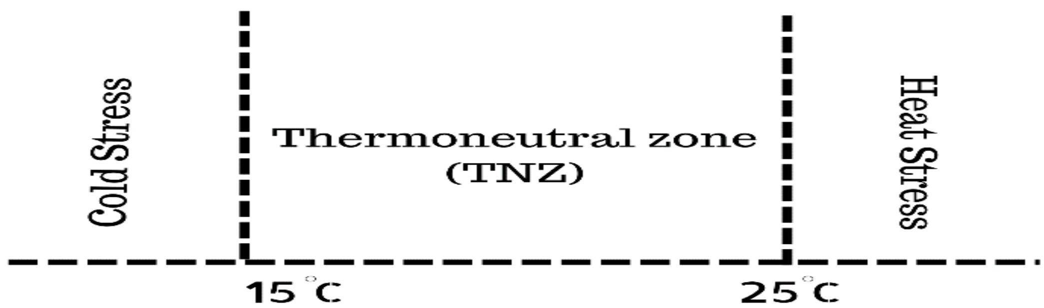

Fig 8.

Fig. 8. Shows, Thermoneutral zone (TNZ) of a lactating dairy cow (modified from C. A. Becker 2002). (C.A. Becker, 2022)

Discussion

Our findings suggest that general health monitoring holds promise as a solution to the body temperature issue. Because cattle have thick skin, the Mlx90614 sensor provides inaccurate readings of body temperature. However, after conducting an experiment, we realized that we could obtain accurate readings of upper skin temperature, so we decided to convert body temperature to skin temperature in order to detect heat stress on cattle.

Heat stress is caused by a combination of environmental factors (relative humidity, solar radiation, air movement, and precipitation) (Habeeb, 2018). Ambient temperature and relative humidity combinations that produce mild heat stress (THI 72 to 79), moderate heat stress (THI 79 to 89), and severe heat stress (THI > 89). (Habeeb, 2018). Also, our findings show that pulse rate in (BPM) and activity status can be used to measure sleep status.

Conclusion

In vast farms where staff do not have enough time, it is challenging to regularly observe the health of the cattle physically so we came up with a general health monitoring system. we come to the conclusion that the discipline of animal husbandry uses an automated method for monitoring the health of cattle. Real-time monitoring of a cow's general health is possible with the technique used in this paper. The system was tested on dairy cattle reliably and successfully. Since the electronic components are inexpensive, the system is cost-effective. Thus, the system can monitor a cow's general health effectively.

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