

IoT-Enabled Livestock Health Monitoring Systems to Improve Efficiency and Reduce Mortality

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Abstract. In terms of livestock monitoring systems, IoT is used to monitor the health metrics such as heart rate and temperature in real time. However, it is this same data that now provides critical data for early detection of health problem, thus enabling timely interventions and optimal practices in the management. Continuous health parameter monitoring and analysis of these health parameters have been improved considerably which resulted in the mortality rates, animal welfare and operational efficiency improved considerably. Real time data collection and processing is done by the IoT enabled livestock health monitoring system by means of heart rate and temperature sensors together with a Raspberry Pi. With a GSM/GPS module integrated with Raspberry Pi, which was connected to a GPIO, it can send data using an ESP8266 module for tracking location and cellular access. Powered by a reliable input source, the system runs constantly and sends data to the cloud where it is monitored remotely at any time through a web interface. If parameters deviate from normal ranges, real time alerts are generated to notify suitable authorities for timely health intervention and improve their livestock management. Results of simulation show a power consumption of about 5 Watts for reliable operation and constant monitoring. Accurate GPS tracking data represent livestock's spatial distribution that serves as a basis for conducting targeted health checks and ensuring optimal use of resources. The system overall improves livestock management through constant delivery of the real time health insights, enabling timely responses and by allowing stable power operation, thus saving operations costs.

1 Introduction

Agriculture, importantly, is chiefly dependent on livestock for it provides many more benefits than just food and these include being home to and hosts of numerous pests and symbionts.

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Meat, milk, eggs and wool are all essential for human nutrition and provide an economic stability to the livestock industry. Apart from these direct products, livestock is necessary for ensuring soil health through manure deposition, a natural and vital process of enriching it with nutrients for growing crops sustainably. It works quite organically, as it does not rely on synthetic fertilizer substitutes as much as other agricultural systems. In activity, livestock also helps promote crop rotation systems and mixed farming, enhancing resource efficiency at the farm level and reducing the negative impacts on the environment as well as improving the farm's resilience to market and climate ups and downs.

By the integration of livestock in farming operation, it forms a symbiotic relationship between crop production and animal husbandry. It synergizes farm profitability, fertility of soil, agricultural systems and positively affects both the farmer and environment. Nevertheless, the increasing demand for efficient and environmentally friendly operation of livestock is justifying the need for developing efficient monitoring systems.

The modern livestock monitoring technologies, through sensors, IoT devices, and data analytics overcome some fundamental problems related to livestock management. Manual monitoring based in the traditional way is a laborious, error prone and inefficient method to monitor at a large scale. Real time insights available in IoT enabled system about animal health, behavior and environmental conditions help detect problems like infections, diseases or injuries at the earliest. The use of these systems leads to the improvement of animal welfare, reduction of mortality rates and productivity improvement through timely interventions. Sensors worn on the body as part of a smart collar measure both movement and grazing behaviour, animal feeding and providing that actionable data for managing herds and improving feeding strategies.

Adoption of IoT based livestock monitoring is more sustainable because it eliminates wastage of resources and improves the operational efficiency. Rather, by utilizing these technologies, the farmers can assure the health and agricultural advantage of their livestock along with long term economic and ecological benefits.

2 Literature review

Visual observation has continued to be one of the most traditional and simple means of monitoring livestock health and behavior [10]. Basically, in this technique, farmers or caretakers check the condition of animals by regular inspection. Monitoring for such visible signs of health matter sucks in observers looking for mistakes like changes in posture, abnormal movement patterns, or even changes in physical appearance. An example of this would be if, for example, one suddenly doesn't have as much activity level or, for example, his/her eating habits have changed. Visual observation may seem simple and there is little need for advanced technology, but there are, however, various limitations. Secondly, the relative accuracy of this method depends a great deal on the experience and attentiveness of the observer. Trained less or less vigilantly, caregivers may miss that subtle sign that something may be wrong and, as a consequence, might fail to intervene. In large herds, visual observation is also rather laborious and time-consuming, and even more so when following all animals all of the time becomes an impossible task [11]. It also does not have the ability for continuous collection (or quantitative data collection as opposed to just qualitative data collection). The tagged animal's absence of a systematic data recording prevents tracking of the less visible changes in the animal's health with time thereby reducing the capacity for trend detection and preventive measures for potential problems. A second traditional method

entails keeping very complete manual records of numerous livestock parameters, for instance, feeding schedule, breeding history, and for instance health events [12]. The method usually involves paper logs or basic spreadsheets to document and track data. Manual records, however, present limitations: They record the historic account of the practices in herd management. Because the process is inherently prone to human error, there are records inaccurately logged, incomplete, or inconsistently updated. That means that gaps in data and lack of reliability also happen. In addition, managing and analyzing large volumes of manually transcribed data can be cumbersome and, most of the time, inefficient. Trends or data-driven decisions are often hard to come by and take a very long time to identify without real-time data. Decisions are therefore often based on stale information which may not be an accurate representation of the current status of the livestock.

In livestock management, there have been long used physical tags, for instance, ears, collars, and leg bands to identify and track animals individually [13]. Usually, these tags contain major information like the animal identification number, breeding history, up to the date vaccination, etc. The main advantage of physical tags is that they uniquely identify each animal for record-keeping and allow for tasks such as tracking lineage, healthcare interventions including vaccination, and compliance with vaccination schedules. However, physical tags have several serious limitations associated with them. Physically durability is a big problem for the tags. Environmental factors that can damage ear tags and collars include harsh weather conditions rough handling, or even physical altercations between animals [14]. By causing gaps in identification and record keeping, damaged or missing tags make it more complicated to manage and errors can be made in tracking and health management. Physical tags also have a limit where the information updates manually. To for instance update a record if an animal had received a new vaccination or went under a health treatment; that information has to be updated manually in the record system [15]. It is a laborious and prone-to-error process, especially in herds where the volume of updates to keep track of can be large. Additionally, physical tags make it so that you do not have real-time information on the health and behavior of the animals. Physiological parameters, levels of activity, or behavioral changes are not among the metrics that they monitor. As a result, physical tags are useful for identification and rudimentary note-keeping but insufficient for a continuous, comprehensive basis for monitoring animal health and welfare [16]. They fail to negate the fact that physical tags, although they persist in the market, are simply inadequate for more advanced, and more integrated forms of monitoring. With the use of modern solutions like electronic identification systems and IoT-based monitoring, we have real-time data and complete information and solve a lot of the shortcomings of your related methods.

3 Proposed work

In the proposed IoT-enabled livestock health monitoring system, the heart rate and temperature sensors are attached to a Raspberry Pi that collects real-time data and processes for analytics. With the Raspberry Pi interfaced with the ESP8266 module, it connects to the GPS module to track the location and the GSM module to provide cellular connectivity to the web server that accepts the data via the ESP8266 module. It operates continuously with a robust power supply. For the monitoring, the data is uploaded to the cloud. The data is made accessible through a user-friendly web interface which alerts the user on any abnormal parameter. It improves efficiency in livestock management as well as mortality by providing timely interventions in health.

3.1 System architecture

The objective of the proposed work is to facilitate animal management by using advanced IoT components for continuous monitoring of the vitals of an animal. It is designed to increase the efficiency of emptying pens as well as minimize mortality rates amongst livestock, important to all farmers and veterinarians. The sensors that are placed at the heart of this system are those of heart rate and temperature for the collection of real-time health data in the livestock. Thus, the IoT module (bottom sensor assembly) consists of these sensors and, more specifically, core information about the animals' well-being. These sensors are crucial for collecting the data that will trigger an early detection of some health issues and potentially save lives based on early detection and possible interventions. Raspberry Pi is the central unit of the data processing unit that interfaces with the sensors through an A/D converter. With this setup, it is possible to aggregate and preprocess data efficiently, before transmission of the information. With its versatility and computational power, the Raspberry Pi is an ideal choice for the real-time job of health monitoring. The system has a connectivity key aspect, and an ESP8266 module with Wi-Fi capabilities is used to transmit data to cloud servers.

Real-time tracking is also done using GPS and GSM modules, which help communicate via the cellular network. Such modules allow farmers and veterinarians to monitor livestock health and distance remote, to get a complete view of the status of their livestock at any time. It is important to keep the whole system running without interruption and a reliable power supply to be provided. It is critical to ensure constant monitoring as any downtime will risk missing health alerts, and it can cause harm to the livestock. Designed to be robust and dependable, the system is designed to greatly reduce the risk of power-related interruptions. ESP8266 module collects data and sends it to a web server where it is merged with the cloud services. It provides a way for remote monitoring and data storage thus making it easy to access historical data and trends. In other words, the web server is an onroad IoT device data flow bridge correlating with the cloud to make data flow and real-time updates. A user-friendly interface is also provided for farmers and veterinarians to access and monitor livestock health data by web-enabled devices. The goal of this interface is to provide easily interpretable data to the advantage of the user so that he/she understands what to do in terms of the health and management of their livestock. Such a comprehensive IoT-based system makes livestock health monitoring affordable, more proactive, and more effective in curtailing mortality rates.

3.2 Implementation

This design of livestock health monitoring system is to have the information collected of an animal being acquired and transmitted at the right time. We first introduce the video camera and its integration of heart rate and temperature sensors attached to the livestock. The Raspberry Pi is connected to these sensors with an A/D converter which gives accurate digital data conversion. The data is collected once, the Raspberry Pi then processes all the sensor data that it is sending, applying needed filters and algorithms so the data is accurate. ESP8266 module used for Wi-Fi connectivity helps in transmitting the processed data to a web server. In addition, GPS and GSM modules are configured to supply location data as well as keep a connection despite sparse Wi-Fi availability. Continuous operation of the system is dependent on power management. A power supply system is designed for optimized power consumption, increased battery life, and reliable performance. Raspberry Pi sends its data to the web server which uploads it to a cloud platform where it can be remotely accessed, stored,

and analyzed. With this setup, farmers can check up on livestock health from almost anywhere, so that necessary interventions can be made once needed.

The raw data which is collected from heart rate and temperature sensors and GPS location are the primary inputs in the algorithm. The physiological parameters and location tracking are all based on these inputs. The data from heart rate and temperature are converted into digital signals as well as filtered to obtain precision and accuracy. Besides the processed heart rate and temperature values, the current GPS location, and the status of power management, the algorithm outputs include. They are transmitted through the available networks (Wi-Fi or GSM) uploading the data to the cloud for further analysis. Also, the outputs are displayed on the user interface to provide real-time allows for users to see the outputs.

Table 1. Algorithm 1: Livestock health monitoring algorithm

<p>Algorithm 1: Livestock health monitoring algorithm</p> <pre>Step 1: Sensor Data Collection initialize_sensors() while system_active: heart_rate = read_heart_rate_sensor() temperature = read_temperature_sensor() Step 2: Data Conversion and Processing digital_heart_rate = analog_to_digital(heart_rate) digital_temperature = analog_to_digital(temperature) processed_heart_rate = filter_data(digital_heart_rate) processed_temperature = filter_data(digital_temperature) Step 3: Data Transmission and Location gps_location = read_gps_module() if wifi_available(): transmit_via_wifi(processed_heart_rate, processed_temperature, gps_location) else: transmit_via_gsm(processed_heart_rate, processed_temperature, gps_location) Step 4: Power Management and Cloud Integration manage_power()</pre>
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The system is an algorithm to efficiently collect and process sensor data from heart rate and temperature sensors. First, sensors are activated and the system continues to collect data in continuous mode while in operation. Analog versions of the heart rate and temperature readings are filtered for accuracy and converted into digital form. Simultaneously, GPS data is gathered. Data is transmitted over the network, i.e. Wi-Fi or GSM depending on network availability. The processed data, together with location info, are uploaded to a cloud. Power management is in charge of optimal energy use. Afterward, the user interface will be updated with the latest data to monitor real-time and integrate.

4 Results

This system needs to contain several, as a minimum, key components. Combining such high-precision IoT sensors of heart rate and temperature with a GPS module for location tracking is essential for real-time measurement. To monitor this sensor data at minute timescales, a robust data acquisition system is required to aggregate this sensor data. Continuous data volume is huge. Therefore, it should be stored in cloud in a large capacity and provide secured access. For time series data (trend of heart rate and temperature, pattern of power consumption, and GPS coordinates) advanced analytics software is important to process and visualize that. Moreover, a usable backup power source along with a steady power supply is

needed to keep the sensor continuously operational, and in particular for getting real-time data to convey to distant places. Collectively, these components would ensure the performance of the monitoring system and therefore accurate health assessments and timely interventions.

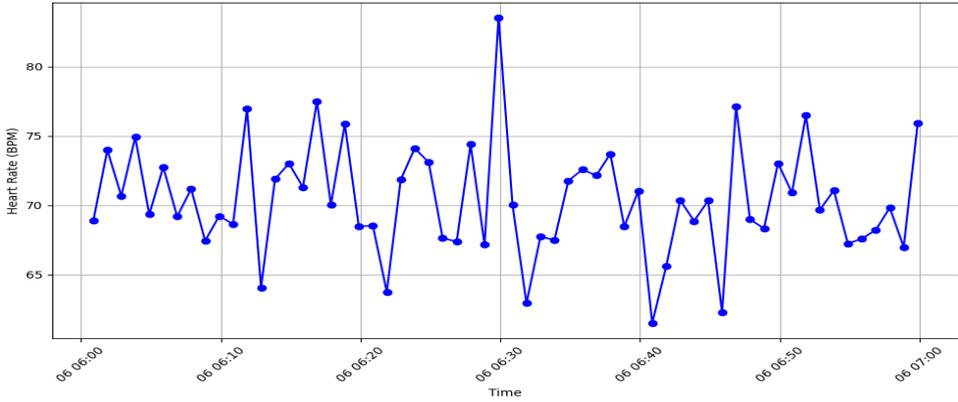


Fig.1. Heart rate over time

Fig.1 shows simulated heart rate data of livestock for 60 minutes while heart rates of livestock are reported at each minute. However, this data is very useful to compute the effectiveness of IoT-enabled livestock health monitoring systems. The drawing of the fluctuating line represents the real-time tracking of heart rates, which makes the continuous check of livestock health possible. Monitoring is constant so this allows for the early detection of any irregularities or distress signals like unusual spikes or drops in heart rate, or even other issues that might occur. Improvement of these systems automatically provides immediate feedback about the physiological status of the livestock to respond immediately to alleviate health problems, which makes it possible to solve them before those problems aggravate. Thus it reduces overall livestock mortality rates by preventing severe health complications. Also, data can be used to optimize management practices and the allocation of resources by identifying health trends and patterns. Fundamentally, this kind of health monitoring system for livestock using IoT provides an improvement in operational efficiency as well as the overall health of the livestock, all of which help drive the goals of modern, data-based agricultural practices.

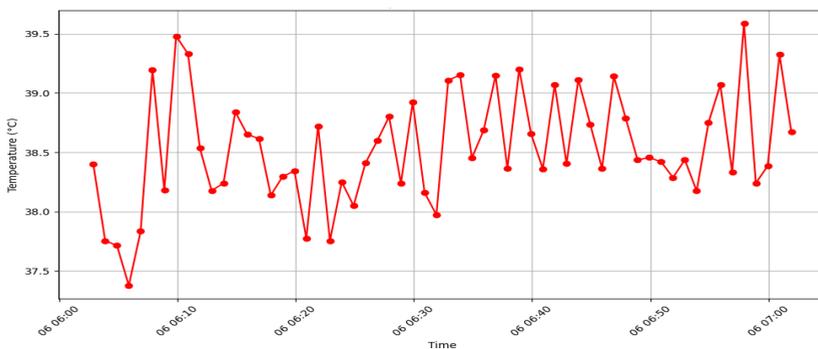


Fig.2. Temperature over time

Fig.2 shows a simulated dataset demonstrating the temperature variation over 60 minutes, which is an important part of IoT-enabled livestock health monitoring systems. Therefore, in such systems, continuous monitoring of environmental conditions such as temperature plays a key role in ensuring the livestock's health is optimal. The time of day is plotted on the x-axis and records the temperature in degrees Celsius on the y-axis; the time increases by one minute every minute. They were interfered with at nine designated historical sites by air. The temperature readings from these points are shown by the red line with markers and the mean value is 38.5°C. They can be ascribed to the system's dynamic nature and its capacity to sense small temperature changes. IoT-enabled systems can analyze temperature trends and identify the anomalies that may indicate possible problems in the health of livestock or environmental stress. Primarily, timely detection and subsequent response to such anomalies are necessary to prevent health problems enhance efficiency, and reduce mortality rates. Real-time monitoring and analysis of such data allow intervention to be made promptly, to the benefit of the welfare of the livestock and the effectiveness of the operations.

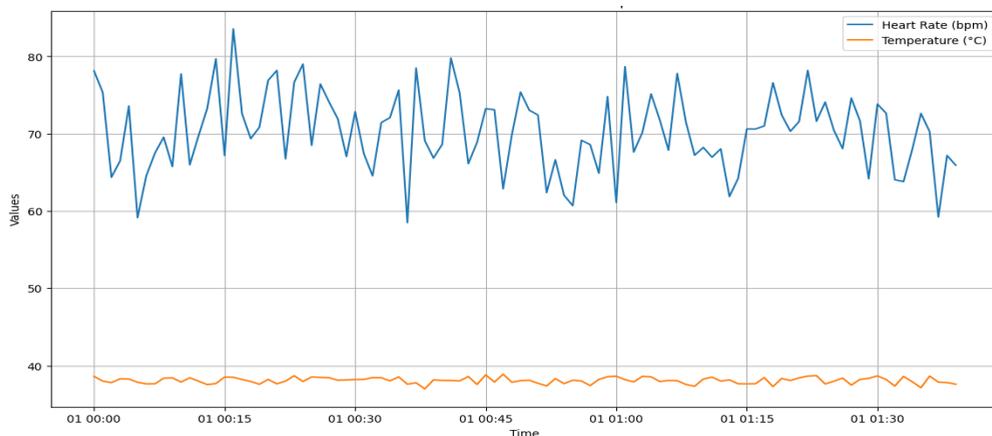


Fig.3. Sensor data comparison

In Fig. 3, time series data of heart rate and temperature, two vital signs for livestock, are shown. The readings of heart rates (bpm) and temperatures (°C) are plotted on the x-axis and y-axis, respectively, as a function of time. During normal animal health, with a fluctuation around 70 bpm of the heart rate and 38°C of the temperature, it shows normal variations as well. Real-time monitoring of livestock health parameters is possible through this continuous monitoring and any deviations from normal ranges can be detected as soon as possible. Real-time monitoring of these metrics serves as a means to the end of bettering the efficiency in livestock management. This helps in identifying possible health problems or stress early and taking prompt measures to handle them. This approach is not only for increasing operational efficiency but also for reducing mortality rates promptly of interventions.

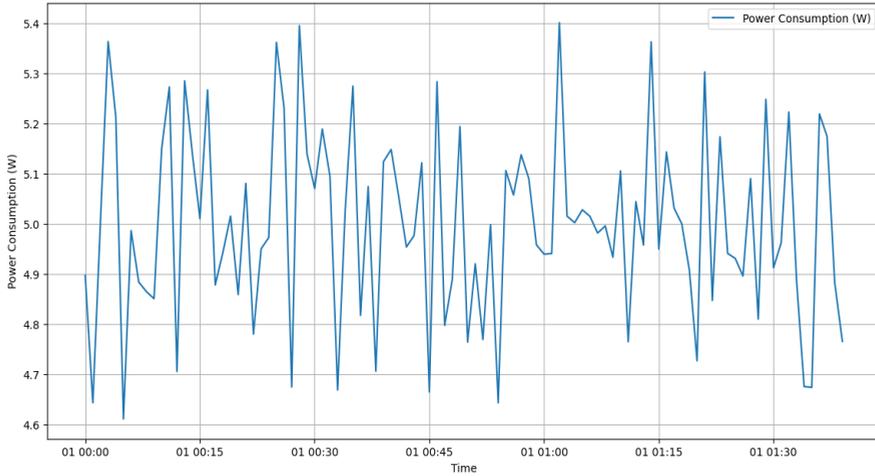


Fig.4. Power consumption over time

Fig. 4 shows how the power consumption of an IoT-enabled livestock health monitoring system changes over time. The data was simulated by changing the mean value of 5 Watts and standard deviation of 0.2 Watts to see the change in power usage over the monitoring period. The dated time series plot indicates that the system has reasonably stable power consumption, with minor fluctuations. The ability to run IoT-powered systems at this power usage stability is crucial when evaluating the efficiency of the IoT system. The system can run reliably without frequent maintenance or operational interruptions because it has guaranteed consistent and efficient power consumption. Such systems are efficient in reducing Operational costs and the monitoring of livestock health should be continuous. Also, a steady operational state capability to keep the system at constant power consumption indicates its ability to avoid the system which could affect livestock health and hence the mortality rate.

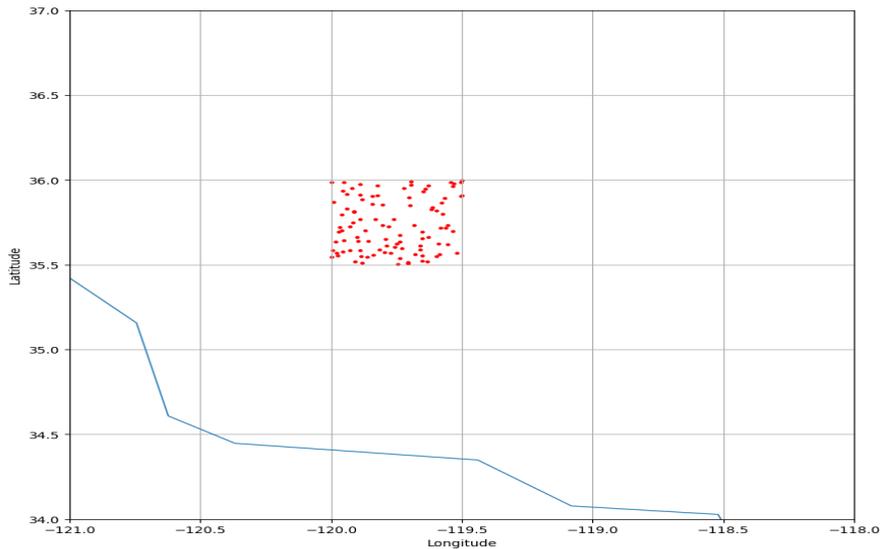


Fig.5. GPS location of livestock

Fig.5 shows the spatial position of livestock monitored in a defined region of California. Such representation is important for understanding the geographical spread and movement pattern of livestock in IoT-enabled health monitoring systems. The graph can be used to assess the efficiency of these systems in tracking livestock by plotting GPS coordinates on a map. Efficient tracking guarantees to make timely interventions on location-specific based data for better overall health monitoring. Such clustering or dispersion of the points may indicate areas that should be more closely monitored or intervened upon. In addition, visual analysis of livestock distribution aids in the allocation of resources and reduction in mortality rates.

5 Conclusion and future work

The IoT livestock health monitoring system is in the form of heart rate and temperature sensors integrated with Raspberry Pi that collect real-time data. ESP8266 module is used for data transmission to a web server through GPS and GSM modules for following and connectivity. It results in a stable power consumption of about 5 Watts, allows for timely health interventions, and a reduction in mortality rates and management practices through real-time alerts and remote monitoring using the cloud. Future developments include improving the sensor accuracy, including other health metrics, and the system scalability. Retrospective and prospective analysis will be conducted using advanced analytics and machine learning algorithms to make predictive inroads and result in lower shares of mortality. No consideration will be given to expansion to different livestock types or environments.

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