International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

KAMADHENU- Microcontroller Based Health and Feed Intake Monitoring System for Dairy Cows

Asha S. Manek[1], Sharon Christa[2], Vineeta*[3], Anuradha Kondelwar[4], Shruti Vashisht[5], Geeta Tripathi[6]

Submitted: 27/04/2023 **Revised**: 26/06/2023 **Accepted**: 05/07/2023

Abstract*:* The surroundings of cattle and the amount of grain that each cow consumes both affect the health of the cows and their ability to produce milk. Monitoring the feed intake condition of cows, together with cattle movement, are the two factors that make it difficult to identify and treat diseased cows early. Dairy farms aren't automated in places like India. Additionally, the cattle are scarce and graze in open areas. Tracking the movement of the cattle is therefore crucial. The goal of this study is to create an automated KAMADHENU neck band which monitors feed intake, cattle behavior, global positioning and real time location of dairy farm cows. The KAMADHENU automated monitoring system analyses the sensor data for the cows' temperature and pulse before determining whether the cows are healthy or not. The KAMADHENU measures cow's behavior and records its activities under farm conditions with the advantage of small size, light weight and low power consumption sensor based electronic device. The overall performance of the proposed system is based on Node microcontroller and sensors. The KAMADHENU neck band performs better with accuracy greater than 90%. Further, in context to the Indian scenario the proposed system represents a better performance over existing systems and evaluation methods.

Keywords: *Cattle behavior, Feed Intake, Node Microcontroller, Sensors, Precision Cattle Farming, Cattle Monitoring,*

1. Introduction

India has a cattle population of about 305 million head in 2021. India had the most cattle that year, followed by Brazil, China, the United States, and the world as a whole, which had over 996 million cows [1]. Sheep and cattle are in great demand, and their costs have been rising over time. In the past five years, small pastoral families have started to combine, creating huge pastures. Because of the high expense of labour, it is unrealistic to rely solely on people to keep an eye on things. The development of smart animal husbandry is aggressively encouraged by legislation and is receiving major financing at the same time that the Internet of Things and digital technologies are rapidly growing. As a result, automated techniques have enhanced the conventional cattle sector, and corporate digitization has gained popularity [2]. Farmers in India still rely on cattle as a source of revenue. Because they rely on dairy products for their livelihood, the majority of farmers and rural residents depend on the health of the cattle [3]. Additionally, farmers rely on cattle for their agricultural needs since they cannot afford sophisticated machinery. The development of livestock production in the modern era necessitates continual monitoring and attention to the health and feed intake of cows. To guarantee maximum milk output, the grazing behaviour of each individual cow can be controlled to match their precise feed consumption [4].

Animal husbandry in modern day is facing challenges like never before. With the rise in population, the need for by-products of animal farming is on a rise in order to meet the nutritional needs [5][6]. The farmers are under pressure to increase their productivity, which in turn will need large manpower and other resources. With the price going up and imposition of minimum wages, animal husbandry at a large scale will incur more expenditure than the income. On top of that, there is a drastic rise in diseases among domesticated animals. Zoonotic disease outbreaks in different parts of the world weakened the animal husbandry industry further.

To determine whether farm animals are healthy or not, the major representation of animal welfare, health issues, and social interactions is employed. Fresh grass continues to be a key component of dairy cow diets in many temperate countries. To meet the nutritional requirements of high-production dairy cows, it is difficult to sustain high levels of dry matter intake (DMI) in pasture-based systems. In a pasture-based system, a range of plant and animal parameters, including the nutritional content of the pasture, animal breed, and pasture amount, influence an animal's capacity to meet its nutritional needs. Further nutritional needs can differ dramatically across individual animals [7].

[1]*T. John Institute of Technology, Bangalore, INDIA*
ORCID ID : 0000-0003-1336-2679
[2] *MIT ADT University, Pune, INDIA*
ORCID ID : 0000-0001-6717-2200
[3] *Apex Institute of Technology, Chandigarh University, Punjab, INDIA*
ORCID ID : 0000-0003-2199-9274
[4]*Priyadarshini College of Engineering, Nagpur INDIA*
ORCID ID : 0009-0005-3164-8541
[5]*Manav Rachna International University, Faridabad, INDIA*
ORCID ID : 0000-0001-5907-0386
[6]*GNITC, Hyderabad, INDIA*
ORCID ID : 0000-0003-4330-1666
** Corresponding Author Email: vini.upmanyu@gmail.com*

The incentive for an animal to engage in eating behaviours like grazing and rumination within pasture systems may be influenced by a number of factors, such as lactation stage, parity, and milk supply. In commercial herd, grazing groups are usually made up of a variety of individual animals at various lactation phases and milk yields, which affects the amount of nutrients needed for both animal care and milk production. While academic research typically refers to pasture allocation rates on the basis of a single cow (e.g., 15 kg dry matter (DM) cow1 & day1), in practice, this allocation rate is applied to the entire grazing mob, allowing animals to ingest more or less than the desired rate of intake. This can result in intense competition and unpredictable intake rates and pasture quality, in addition to the inherent variation in individual animal nutritional requirements within a grazing mob [8].

In addition to the knowledge and experience of the farmer, modern sensor technology in agriculture aids in decision-making. Indicating whether or not intervention is necessary, binary systems enable farm workers to respond swiftly to crop and animal reactions. Although many precision farming technologies have previously been adopted in the arable farming industry, their adoption in the livestock industry is crucial because it can increase consumer confidence and product traceability. The use of sensor data in livestock farming is becoming more and more crucial for proactive control of animal welfare, health, and productivity as opposed to reactive management. The improved accessibility of data helps with animal identification, monitoring, and management of production in accordance with established standards. Individual animal predictions that account for physiological changes over time and may even incorporate data from several sensors have the advantage of identifying weaknesses in huge herds before humans do, but they also generate a lot of data, necessitating machine learning techniques [9].

The device named KAMADHENU, which is proposed by the authors, is designed, integrated and tested for its performance and the same is compared for its performance with the existing devices. This paper presents cattle monitoring device that can be worn as a belt. Further, the paper is organized as follows: the authors conducted a detailed survey of the existing cattle monitoring systems proposed and available, the same is presented as related work. The need for designing cattle monitoring system specific to the Indian scenario is presented in the factors leading to proposed research, which is Section 3. In Section 4, the parameters considered for designing the IoT based device are elaborately presented and justified. System design and implementation is presented in Section 5 followed by results and discussion in Section 6 and Section 7 presents the comparison of the performance of the designed device and the existing devices which is followed by conclusion in Section 8.

2. Related Work

Mayer et al. [10] conducted three experiments to monitor the real time health and behaviour of domesticated animals. With this regard, the authors selected cattle as the case study and placed matchbox sized motes that monitors intra-ruminal activity and enabled wireless communication between sensors and mobile telephone network. Based on the real time view of the data obtained via the internet the authors could monitor the internal activities of cattle subjected in the experiment. The researchers used a single-board computer with Atmega128 processor, external EEPROM, and a Sony Ericsson GM47 GSM module. The three experiments gave promising results and established the fact that domesticated farm animals can be monitored for their activities and wellbeing.

Further, the authors of [11] conducted a validation experiment for the feeding and drinking monitoring system they developed for group-housed cattle. A total of 42 Holstein cows, 24 feed bins and 4 water bins were the subjects of the research. The system was efficient with high specificity and sensitivity and was well efficient. But this technique, if adapted in the Indian scenario, the farms need to be more mechanized and an overall makeover which is out of question. The research work presented again makes it evident that cattle behavior monitoring is possible.

The authors of [12] designed a wireless communication device for loose house dairy and free ranging beef cattle to monitor their mobility, activities. The technology developed was adapted to include real time and non-real time data download. Based on the lab and farm trials, the developed prototype function and delivered results with high precision and farmers were able to monitor the animal status, thus improving operational efficiency.

The authors of [13] and [14] proposed the integration of expert systems and machine learning technologies to increase the productivity and profit margin in animal husbandry.

The Suseendran, G. and Balaganesh, D et. al [15] developed an energy efficient sensor-based prototype, communication system and simulation that predict the illness behavior in cattle. The developed device is capable of monitoring the cattle health with 12% higher efficiency than the existing system.

Technology integration in cattle monitoring enables the managers to override the time-consuming manual monitoring process. The existing closed-door cattle farming techniques make technology integration quite easy but open grazing aid in biodiversity and animals grazing in the open pastures will improve soil preservation and sequestration. Inspecting the animals in such a scenario is challenging. The authors in [16] further stated that the by-products from cattle reared in the natural environment is preferred more by the conscious consumers. Therefore, technology can aid in the automated inspection process. Recurrent monitoring with digital technology can reduce labour sustainability also. The same will in turn result in higher efficiency in production. The challenge is adopting developed indoor purposes to open pastures. But the technology has an edge over the manual inspection process.

The real time data generated by sensors around the clock cannot be compared with the inspection conducted once per day. That doesn't mean human intervention can be completely avoided. The data generated by sensors are objective and the information from the same can only be verified with manual follow up. With human judgement, the analysis of the sensor data can be justified.

3. Factors Leading to Proposed Research

1. The primary factor influencing ruminant animal growth, development, and lactation is feed intake. The dairy industry in India has risen alarmingly since the so-called 'white revolution'. One of the key factors determining lactation is the intake of dairy cows. The majority of the feeding detection technology available today, nevertheless, are intended for dairy cow herds. Correct feeding information is necessary for individual dairy cow feeding detection; however, it is impossible to assess each dairy cow's nutritional status individually.

2. Accurately tracking each dairy cow's feeding behavior is the most important step in obtaining digital breeding of dairy cows. As a result, the industry for intelligent dairy cows has concentrated on applying technologies for artificial intelligence to analyze the feeding habits of specific dairy cows.

3. The individual food consumption of the dairy cows can also be used to estimate their health state. Dairy cows can be warned in advance if anomalies are found, prompting herders to reduce the financial loss brought on by illness or death. Calculate feed reserves depending on dairy cow consumption and price to prevent running out of feed or wasting feed. In addition, the quantity of labor required by large-scale farms can be reduced by approximating the milk production of individual cows based on feed consumption. The breeding industry aggressively implements accurate and effective breeding in response to the government's policy on clever animal husbandry.

4. The food quality and security of dairy cows are constant worries or cattle owners. Pathology and disease resistance are undoubtedly impacted by better-raised cattle. To evaluate the health, welfare, and comfort of dairy cattle on the farm, it is helpful to observe their behavior. Certainly, alterations in behavior are obvious warning signs of welfare and health issues with dairy animals. Consequently, these can be incorporated into an early warning system as input. For the animals to produce milk, they must spend a significant amount of time either lying down or eating. Therefore, being aware of their position is crucial for monitoring and managing their behavioral patterns and activities in order to gather data on their productivity and health. An issue might also be caused by environmental factors including drought, heat, or plant poisons. As a result, numerous researches have concentrated on the usage of health monitoring systems that should be able to recognize different behavioral factors and turn them into relevant behavioral modes (standing, walking, lying down and grazing). These solutions could help the owner improve animal welfare and milk output.

4. Parameters Affecting the Grazing Behavior of Cows

4.1. Body Temperature

The typical method for determining animal stress is to take its temperature. For a long time, veterinarians routinely took rectal temperatures to identify and diagnose febrile diseases. Numerous anatomical locations on cattle, including the vagina, udder (milk), ear (tympanic), and the rectum, have been used to monitor the temperature. Animals typically maintain a body temperature of 38.6°C. To support the body's physiological operations, the temperature must be kept within safe ranges. According to the literature, the usual temperature range is between 37.8 and 40.0 degrees Celsius.

4.2. Footrot

When the environment is muddy and moist, a pathogen found in dirt contaminates the hoof tissues and causes this disease.

4.3. Wasted Illnesses

The same species of bacteria (Mycobacterium) that cause tuberculosis and Johne's disease that affect cow performance.

4.4. Production Disease

In addition to genetic and viral problems like hanging placentas, production diseases can include nutritional and metabolic disorders. The production diseases are mostly to blame for the financial loss to the dairy industry and the wellbeing of cattle. There are many reasons why abortion occurs, including BVD on the foetus during the gestation stage. Prenatal BVD virus infection causes weak calves, ovarian cysts, foetal mummification, and early deliveries. Abortions may also result from heat stress, listeriosis exposure, and forb-derived toxins during gestation.

4.5. Parasites

Numerous parasite species need cattle waste to complete their life cycles. Flies were discovered to hatch in locations linked to manure accumulation in research on fly populations conducted on feedlots and dairies. Roundworms and other internal parasites need on dung pats for a moving away from manure towards a more suitable environment for growth while in the early larvae stages where cattle unintentionally eat them in the grass. The cattle congregate Fecal material gathered in higher concentrations in order to protect against foreign parasites. Therefore, it seems that cattle may be increasing their risks of accidentally consuming internal parasites that are moving off of faecal material in an effort to avoid flying parasites. In regions where cattle congregate, the risk of roundworm exposure for cattle may rise. Animals may, however, refrain from grazing in faecal concentration zones to prevent parasitism. In addition to internal parasites, feeding areas where old hay and dung have collected might have an increase in fly populations, generating breeding grounds.

Internal and external parasites are the two types of parasites that cause performance deficits in cattle and their calves [12]. Hairworms, lung worms, liver flukes, and coccidia are common and significant internal parasites of cattle. External parasites like horn flies, lice, and grubs are quite common. Hairworms, commonly known as stomach worms and intestinal worms, are common internal parasites found in the digestive systems of cattle. The eggs hatch, the larvae are removed from the manure by rain, and the infected cattle ingest the larvae on moist grass when the weather is temperate. This is how the worm is spread from infected cattle to humans.

In the late winter and early spring, the larvae of heel flies, also known as cattle grubs, a form of external parasite (warbles, wolves), lay their eggs on the hairs of cattle's lower legs. Grubs are visible on the backs of cattle throughout the winter. Grub migration causes weight loss, slower weight gain, and decreased milk production in cattle.

4.6. Water Location

Cattle typically drink between one and eleven times per day, depending on their biotype and the climate. Limiting access to water can significantly impact their behaviour and performance, including a reduction in live weight gain. Water is considered to be the most critical factor in determining livestock allocation at the paddock scale and can greatly influence land use decisions. In practice, the height of watering spots and the horizontal distance to water are strongly indicative of the distribution of grazing animals, with these two variables negatively correlated with the frequency of visits to water sources. Grazing animals tend to prefer limited areas near trees or water troughs for rumination and relaxation, but certain designated hotspots for grazing exist near water sources.

4.7. Feed Location and Type

Introducing incentives, such as supplements, feed, or salt licks, at specific locations can alter the distribution of animals over a pasture. Such landscape interventions have the potential to modify cattle preferences for certain areas, alter their habitat-use patterns, or influence the distance they travel. These changes can increase the uniformity of fodder and contribute to the restoration of grasslands.

Cattle-grazed rangeland pastures (258 and 339-ha fields) have shown to be responsive to the placement of salt and low moisture blocks (LMB) in low-use areas far from water. When the two supplements are combined, both alternatives stimulate cattle to go further. Similar to how hand-feeding range cake in accessible spots seemed to be a less useful and successful method than LMB placed in higher and steeper terrain to improve the consistency of cattle grazing on rugged rangeland.

5. System Design & Implementation

The majority of the feed intake monitoring devices in use today just keep track of how much feed is produced for the cow to consume. They do not account for the amount of grain that is lost to waste or left unfinished by the particular cow. Overestimating or underestimating the amount of feed consumed can result from the discrepancy between the amount of feed delivered and the amount consumed. This might result in health issues being unreported for much longer than is necessary, which can cause a tiny health risk to become significant by the time it is discovered. Additionally, producers cannot afford to waste feed given the rising expenses of feeding cows. Because the feed is not being used by the cows to produce milk, constant overfeeding of cows merely reduces the profitability of the dairy farm operation. Additionally, underfeeding causes the cow's milk output to be less profitable. Cows can also become underweight or skinny because they will use up their energy reserves before their ability to produce milk is limited. The farming enterprise will be more productive and financially feasible the more precisely the feed intake of each individual cow can be tracked.

5.1. Automated KAMADHENU Neck Band

In this proposed automated KAMADHENU system in order to monitor and record feed intake and cattle behavior, we have used a Node microcontroller and sensors as shown in block diagram Fig. 1. The automated neck band consists of five parts: an ultrasonic sensor, gas sensor, DHT 11 sensor, Node MCU and wireless communication module mobile. We used the Node MCU - 12E module which is based on Arduino. The special chip of Node MCU is ESP8266, which is wireless and Wi-Fi enabled. The sensors are mounted on a neck band which can be tied to cows' neck to monitor body temperature and humidity through the DHT 11 sensor. The wearable KAMADHENU neck band communicates to the mobile device to the server which requires connectivity using WiFi and that power supply relies on battery.

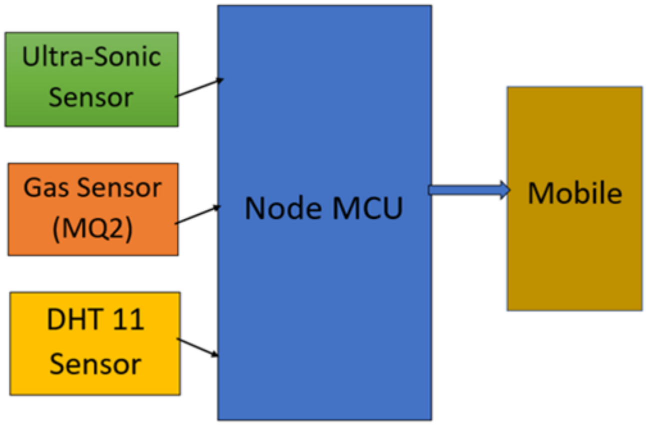

Fig. 1. Block Diagram automated KAMADHENU system

5.2. Components Used to Build KAMADHENU Neck Band

5.2.1. Node MCU ESP8266

An extremely affordable System-on-a-Chip (SoC) named ESP8266 serves as the foundation of the open-source Node MCU software and hardware development environment. It is a Wi-Fi enabled microcontroller that gathers data from sensors and sends it to a mobile device, the cloud, or the internet. There is a total of 17 GPIO pins on the ESP8266 Node MCU. These pins can be used for a variety of ancillary purposes, including:

- A 10-bit ADC channel namely ADC channel
- UART interface that can be used to load code serially.
- PWM output pins for dimming LEDs or controlling motors.
- SPI, I2C & I2S interface for connecting various sensors and accessories.
- I2S interface in case the sound component has to be integrated.
- The ESP8266 module enables a microcontroller to connect to a Wi-Fi network.

Node MCU can be reprogrammed using Arduino IDE that makes it convenient for the users by configuring the IDE to recognize the new board. The farmer may monitor the cattle from anywhere outside the farm thanks to the data that has been sent to their cell phone.

5.2.2. Ultrasonic Sensor

Ultrasonic sensors utilize ultrasonic sound waves to measure the distance of a target object and then convert the reflected sound into an electrical signal. The sensor comprises two main parts: the transmitter, which generates sound through the use of piezoelectric crystals, and the receiver, which encounters the sound after it has travelled to and from the target. To determine the distance between the object and the sensor, the sensor measures the time elapsed between the transmission of the sound by the transmitter and its reception by the receiver. This allows for accurate and reliable measurement of distances and is commonly used in various applications, including the real-time monitoring of cow grazing activity.

Equation (1) illustrates the calculation of the same and distance is presented as D, T and C depicts the passing time and the sound speed (343 meters per second by default) respectively.

$$D=1/2\ T*C \tag{1}$$

Fig. 2 depicts the interface between the Node MCU and ultrasonic sensor. There are four terminals on the ultrasonic sensor namely +5V, Trigger, Echo, and GND. The connection of the ultrasonic sensor pins to the Node MCU is shown in table 1.

Table 1. Pin Connections

Ultrasonic Sensor Pin	NodeMCU Digital Pin
+5v pin	+5v pin
Trigger Pin	Pin 4
Echo Pin	Pin 3
GND	GND

Fig. 3 illustrates the ultrasonic sensors. The sensors emit short, high-frequency sound pulses that travel through the air at the speed of sound. When these pulses hit an object, they bounce back to the sensor as an echo signal. The sensor then calculates the distance to the target by measuring the time between the emission and reception of the signal. This process enables the accurate detection of objects in the sensor's vicinity, making it a useful tool in various applications, including the real-time monitoring of cow grazing activity.

One way to monitor the grazing of cows in real-time is by using a Node MCU microcontroller and an ultrasonic sensor to gather and store sound data. This data is then processed and transmitted wirelessly to a mobile device. This allows farmers to monitor each cow's grazing activity and track changes in grazing time. By analyzing this data, farmers can make informed decisions about the health of their cows and predict any potential issues. This real-time monitoring system enables farmers to effectively monitor the grazing time of their cows and ensure their overall wellbeing.

To meet the specific needs of the application, a time reference point for cow grazing was established for each period of the day. This allows the monitoring system to track changes in grazing activity and issue a warning if grazing time exceeds the established reference point. The design block diagram for the real-time monitoring system with ultrasonic sensor connection is depicted in Figure 1. This system design enables efficient and accurate monitoring of cow grazing activity to ensure their wellbeing.

5.2.3. Gas Sensor

Gas sensor and its interfacing with Node MCU shown in Fig. 4 to measure the gas emissions from cattle. H2, LPG, CH4, CO, Alcohol, Smoke or Propane gases can be detected by MQ2 gas sensors. It is highly sensitive and response time is faster, so measurement can be taken as soon as possible.

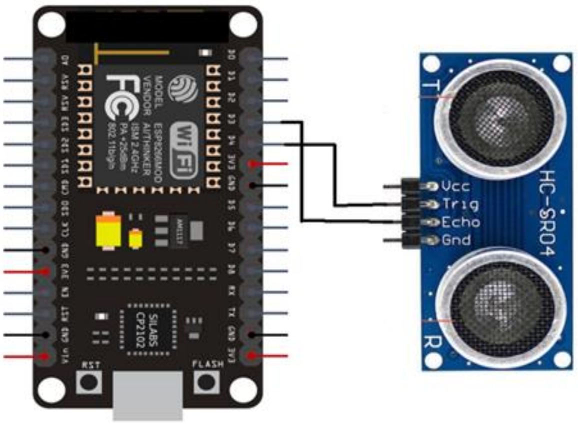

Fig. 2. Interfacing of Ultrasonic Sensor to Node MCU

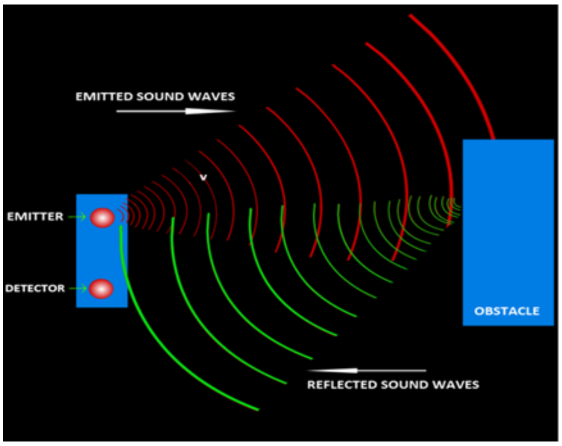

Fig. 3. Sound Pulses/waves emitted by Ultrasonic sensor

The main purpose of using a gas sensor is detection of high concentration of the corresponding gases without additional equipment or environment by mounting the gas sensor onto the neck belt along with the Node MCU. This will help farmers and cattle owners to make decisions on changing the diet of their herd or their method of handling manure which could help in reducing emissions at their farm. This gas detector also provides added value anywhere on dairy farms such as when to mix slurry or where and how to mix/spread slurry etc. Cattle farmers should monitor the ammonia levels as this gas is emitted from cow's urine and manure which will help to compare cows feed and sleep criteria. Increase in ammonia level can cause negative health effects for the cattle.

Similarly, CO2 is another gas that can cause harmful effects for the cattle. When cows exhale, they give off CO2 and it makes the space hazardous when many cows are in a single place and the air is not being ventilated. The MQ series gas sensor employs an electrochemical sensor without any calibration and a tiny heater inside to monitor various combinations of gases. A built-in variable resistor that adjusts its value based on the gas concentration is a feature of the MQ2 Gas sensor. Resistance increases with a low concentration whereas it decreases with a high concentration. A load resistor must be added in addition to the built-in resistor. The value of a load resistor, which can range from 2 k ohm to 47k ohm, is used to modify the sensitivity and accuracy of a sensor. The greater the value, the more sensitive the sensor is.

5.2.4. DHT 11 sensor

The farm environment can play a crucial role in the development of diseases in cows. To monitor this, the system includes a DHT 11 sensor that tracks the ambient temperature and humidity on the farm. This sensor provides a calibrated digital output signal and enables the farmer to receive notifications on their mobile device when there are significant changes in temperature or humidity. This temperature and humidity sensor complex is a vital feature of the system, as it allows for early detection of potential health issues in the cows and prompt action can be taken to prevent any further complications.

Interfacing of DHT 11 Sensor to Node MCU is shown in Fig. 5. The complete KAMADHENU neck band is as shown in Fig. 6 with the sensors interfaced are gas sensor, ultrasonic sensor, DHT11 sensor with Node MCU and mobile device.

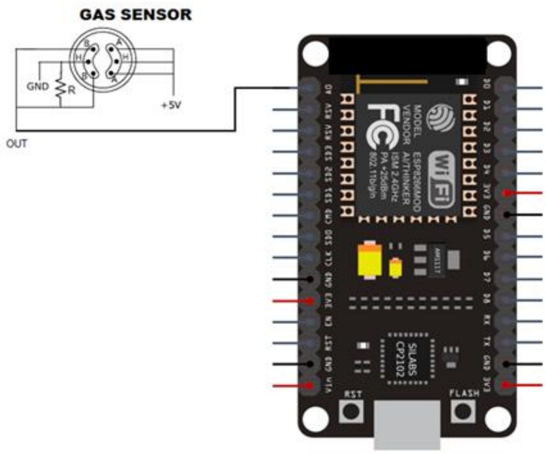

Fig. 4. Interfacing of Gas sensor to Node MCU

5.3. Methodology

When the power is turned on, the power supply from the power module is transmitted to all different types of sensors to detect various changes in the body. Cattle's regular heart rate is detected by heartbeat sensors, and their body temperatures are detected by temperature sensors. The buzzer in this gadget alerts the farmer if there are any deviations from the normal body conditions of the dairy farms. The regular body conditions and movements of cattle will be monitored with the use of Node MCU, producing continuous monitoring of cattle. KAMADHENU neck band use opportunistic data transfer to enable effective, energy-saving, and reliable measurement transmission.

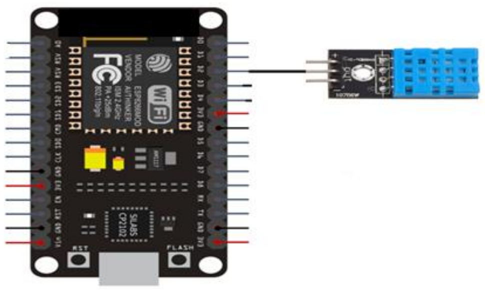

Fig. 5. Interfacing of DHT 11 Sensor to Node MCU

The server plays a crucial function of communication and is situated in the cloud. We had to keep records of the system as a whole. We used databases to store information about farmers (such as FarmerID, Farmername, credentials), cowsheds (such as Shed_size, GPS coordinates), cows (such as Cow_ID), KAMADHENU neck bands (such as Band_ID, Band_name), sensor data, and finally characteristics and alarms. KAMADHENU sensors send data to the server. The server examines incoming messages;

1. It eliminates duplicates
2. It determines whether the message contains the correct pieces of information.
3. It backs up old data to an external server.

The farmer can view information on each individual cow and each group of cows using the end-user Android application. Its functionality is constrained because it is just an illustration of what it would appear like in a business solution. It enables farmers to keep tabs on the health, movement and grazing behavior of a cow and cow herd. Farmers are better able to monitor their cows and respond to any problems more quickly thanks to the information provided via alarms. This is crucial, especially when there are a lot of animals in the herd and the farmer is unable to watch over each one constantly.

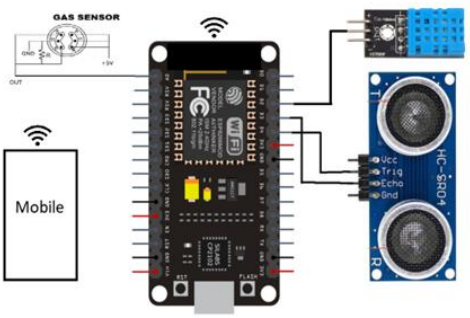

Fig. 6. Architecture of KAMADHENU interfacing of all sensors used for neck band

It was crucial that the data be presented in a way that makes it clear and simple to understand. This includes color-coding and alarm icons that denote various alarms, such as the device-related alarm (informs the farmer about KAMADHENU neck band malfunction), the estrus-related alarm, and the health alarm (which is typically associated with issues with feeding). The farmers can also look up specific details about the cow in question. This is necessary, especially if they want to learn more about why the alarm was raised by the system. As an illustration, activity, contemplation, temperature, or the volume of incoming communications (for the system diagnosis purpose).

6. Results and Discussion

The characterization of grazing behaviour, including grazing patterns, pathways, and preferred regions, is made possible by the use of the proposed automated KAMADHENU neck band as shown in Fig. 7 for COW.

The speed of movements can also be used to distinguish between different grazing activities. The enhanced information provided by KAMADHENU neck band receptors in grazing cows can serve as a useful tool to support the choices required for more accurate pasture management. In this study, we investigated the use of two distinct techniques to observe and evaluate cow's behaviours which includes foraging or grazing, resting, and movement.

- Monitoring movement: Triaxial accelerometers mounted to the neck capture thorough movement registers. This allows us to recognise a wider variety of behavioural patterns than when the accelerometer is mounted on the leg of the cow.
- Tracking an animal's location: GPS sensors are used to record the cow's location, which is then periodically transmitted to a central server within a cloud computing architecture.

Micro Electro Mechanical System (MEMS) accelerometers are used to assess the acceleration levels on the necks of cows. An accelerometer of this kind measures acceleration in three orthogonal directions called as triaxial accelerometer. Since the sensor is attached, data are continuously retrieved and stored in plain text format on an SD memory card. Figure 8 shows grazing pattern of cow with KAMADHENU neck band with Time in x-axis and acceleration on y-axis. On 92 of the 100 observation days, data were gathered. In the second week of the experiment (9-12 August), the cow missed four consecutive observation days because their paddock had accumulated 35 mm of rain and surface water. She has been taken out of the troubled field on August 14 and rotated through other paddocks devoid of surface water for the duration of the experiment. Also, due three days sickness, data collection was not possible on the final day of the experiment.

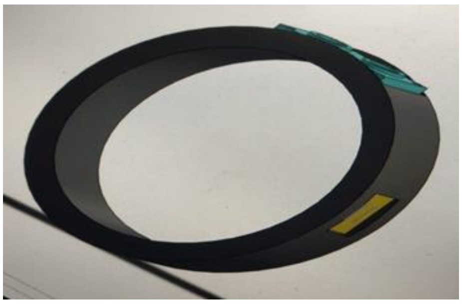

Fig. 7. An automated KAMADHENU neck band for COW

Similar to this, the adoption of GPS "collars" for livestock has made it possible to record precise position data over extended periods of time, enabling a more thorough understanding of ruminant habits and the factors that influence their spatial distribution. With the help of modern GPS technology, individual animals may be located with an accuracy of at least 10 metres.

The position information can be communicated to an owner in real time or during periodic sessions, and it can be saved on compact flash cards together with a significant amount of behavioural and physiological data. Cattle behaviour can also be observed using a collar equipped with sensors for behaviour observation. Estrus occurrences can be identified by analysing the rate of rumination as well as the feeding and resting behaviour. The KAMADHENU neck band performed well with accuracy (>90%) while visual human observation had a far lower accuracy.

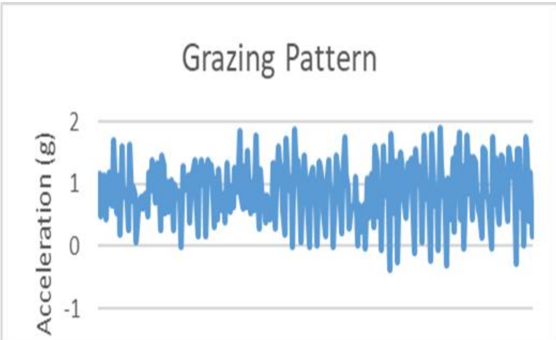

Fig. 8. Time series representation- Grazing pattern

7. Performance Analysis

The objective of the research paper [17] include examining and debating a variety of cattle health issues, as well as addressing the core idea of digital technologies and their importance for cattle health. The paper also discussed several IoT and AI-integrated cattle health monitoring devices, and it presents the prior cattle health monitoring architecture. The article analyses the difficulties and makes suggestions that can be used for future development based on the review. In proposed work KAMADHENU, an automated neck band is developed to monitor cattle behavior.

By categorising and integrating prior research in this area, the aim of this article [18] is to provide a detailed study of the usage of IoT in the livestock business. The paper discusses a variety of IoT-based livestock tracking, management, and monitoring solutions. In order to identify and lower the security risk in the cattle sector, it also looks at numerous security issues in IoT-based design and a cooperative security strategy. Finally, pertinent outstanding research questions in the area of IoT-based livestock management have been discussed. The proposed work KAMADHENU is tested, implemented, and may be utilised for actual applications as opposed to the research work provided in [18]. The suggested work is compared to other recent works that are similar in Table 2.

Table 2. Comparison of Recent Works with KAMADHENU

Work	Study/Implementation	Performance
Singh, D et al., Year 2022 [17]	Discussed several IoT and AI-integrated cattle health monitoring devices, and it presents the prior cattle health monitoring architecture.	The many real-time monitoring systems for cow health have been covered in this study. The article concludes with suggestions for future work that might be used to properly ensure the health of cattle.
Farooq MS et al., Year 2022 [18]	After thoroughly examining IoT-based research on livestock, it is determined that additional study directions are required to offer practical livestock management, monitoring, controlling, and prediction solutions.	Researchers, farmers, and politicians working on IoT-enabled livestock systems might find the survey's findings interesting.
KAMADHENU	Automation of neck band to monitor cattle grazing behavior.	The KAMADHENU neck band performed well with accuracy (>90%) while visual human observation had a far lower accuracy.

8. Conclusion

The surroundings of cattle and the amount of grain that each cow consumes both affect the health of the cows and their ability to produce milk. Another factor that makes it crucial to use feedstuffs optimally is the cost of feeding animals. To prevent financial loss for the farm, it is crucial and advantageous for medium to large dairy farms to regularly check the feed intake of dairy cows, the cattle's environment, and any health issues. The automated KAMADHENU system is developed to keep track of the feed intake, behaviour of the cattle, global positioning, and real-time location of dairy farm cows. The KAMADHENU is a sensor-based electronic device having the benefit of being tiny, light, and low power consumption while measuring and recording cow behaviour on farms. The automated KAMADHENU's overall performance, which is based on a Node microcontroller and sensors, has the ability to record feed consumption and feed efficiency as accurately and truthfully as feasible. When compared to current systems and evaluation techniques, the proposed automated system KAMADHENU neck band performs better with accuracy greater than 90%.

Author contributions

Asha S Manek: Conceptualization, Methodology, Writing-Original draft preparation

Sharon Christa: Software, Field study, Data curation, Writing-Original draft preparation

Vineeta: Writing-Reviewing and Editing

Anuradha Kondelwar: Visualization, Investigation

Shruti Vashisht: Software, Validation

Geeta Tripathi: Field study

Conflicts of interest

The authors declare no conflicts of interest.

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