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Identification of Cow Hoof Disease in Early Stage using Internet of Things (IoT) and Machine Learning

Durairaj K.[1], Dhilip Kumar V.[2], Kanagachidambaresan G. R.[3]

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Abstract- Monitoring the health of dairy cattle is critical in increasing the global supply of dairy products. Farmers are losing interest in the dairy industry because their animals are suffering from a wide range of debilitating health issues, unpredictability in the form of fatal illnesses and advanced breeding costs. The concept of "Smart Dairy Farming" is no longer just a pipe dream; it has begun to take shape as numerous fields, such as machine learning and IoT, have found practical applications in this sector. The hoof holds immense significance within the anatomy of an animal. The main focus to identify the injured cow's hoof in a early stage. In the dairy industry, timely lameness diagnosis is a significant challenge that farmers must address effectively. Lameness can be caused by several foot and limb disorders, each caused by a different illness, management practice, or environmental factor. The significance of lameness prevention, early detection, and treatment in dairy cows cannot be overstated, given the numerous negative consequences of lameness. Early detection of illness allows farmers to take preventative measures sooner, which may result in reduced or eliminated antibiotic use, increased milk production, and cost savings on veterinary care for their herd. This discovery suggests that classification algorithms could be used to distinguish between the behaviors. The proposed CHHMoS(Cow Hoof Health Monitoring System) device equipped with accelerometer, ESP Node32 Microprocessor and temperature sensor helps to monitor the continuous activity of the cow to predict the Cow Hoof Disease in early manner.

Keywords*: Cow Hoof Health, CSHMoS, Machine Learning, Health Monitoring, Animal Behaviour, IoT in Animal Monitoring.*

I.Introduction

Lameness is the inability of the locomotor system to move forward because of problems with how it works or how it looks. Lameness can be caused by pain, deformity, or disease in a joint, a bone, a soft tissue, a nerve, a metabolic process, or an infection. Lameness in draught animals leads to a big loss of money because they can't work as well, and they can't serve the purpose for which they are kept. Half of the time, draught animal owners are the only ones who can cause lameness. This could be due to a lack of knowledge or greed. Better surgical care and ways to prevent lameness will help owners of draught animals lose less money.According to the 2004 OIE Global Conference on Animal Welfare, "in recent years, animal welfare has become one of the most important goals on a global scale." Scientists all over the world have been doing research to improve the well-being of animals during the different stages of production, such as breeding, transport, and slaughtering [1]. These studies have also focused on making and testing automated systems that check on the well-being of animals while they are being bred. Also, these management-relevant indicators can be made if we know how farm managers and consumers feel about the welfare and behaviour of dairy cattle [2].

[1,2,3]Department of Computer Science and Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Chennai 62, India.
[1]duraiit2011@gmail.com, [2]vdhilipkumar@veltech.edu.in, [3]kanagachidambaresan@gmail.com

Animal behaviour is a clear sign of an animal's physiological and physical state. For cows, the most important things they do are eat, ruminate, lie down, and walk, and farmers need to keep an eye on these things regularly to see if the cows are getting the care they need. Operators can directly watch how cows act by using visual observation, but this method is hard and takes a long time, especially on large farms. In the scientific field of precision livestock farming (PLF), solutions based on ICT are now being made and tested [4]. These solutions are meant to make cow monitoring and management work better. These devices currently collect a huge amount of data that, when handled by the best algorithms, could help farmers a lot in keeping an eye on their herd in a way that is both productive and profitable.

In recent years, the number of solutions that combine techniques from artificial intelligence with platforms for the internet of things has grown. Advanced AI has proven to be a useful tool for analysing the huge amounts of data that sensors collect. It has given us new information that we couldn't have gotten any other way. When it comes to raising cows, there are very specific rules about how farmers can care for their animals [5]. Most of the options we have now are hard to do, take a long time, and are therefore expensive. Even though the number of stockpersons to animals in many commercial facilities is high, many livestock producers still rely on stockperson observations to find health and welfare problems with their animals.

Wearable sensors are becoming an important way to keep an eye on the health and activity of cows because of this. When you connect wearable sensors to the Internet of Things and watch how a cow acts, you can learn new things about its health and well-being [6, 7]. Obviously, if you know how long an animal spends doing each behaviour, you can figure out how healthy it is. In the second case, it is hard to keep an eye on the grazing animals because the grazing area grows and the animals act differently when they are free to do so. Also, because there are fewer people watching, it is hard to keep track of any strange behaviour and figure out why it is happening. This makes it hard to keep an eye on strange behaviour and figure out why it's happening.

Most animals have no way of communicating any sort of illness to humans. Healthcare Monitoring Systems (HMS) developed a wireless sensor for wildlife based on the results of this study. A forest official's office and any forest veterinarians will be notified if this sensor detects any animal health issues. This data can then be used to learn more about the individual or provide medical care. The proposed WSN is an excellent method for installing multi-functional WSN gateways in a decentralised region in order to provide efficient and cost-effective services for a wide variety of application fields, such as monitoring systems, agricultural production, environmental control, military activities, and so on. The proposed WSN includes temperature, smoke, pulse, respiration, heart rate, and an electrocardiogram (ECG) sensor. The implications for monitoring in a wide variety of contexts are profound. (Islabudeen, M., P. Vigneshwaran, M. Madhuri, B.M. Kumar, J. Ragaventhiran, S. Sharmila, and G. Islabudeen Vigneshwaran Madhuri, S. The wireless gadget can communicate with other networking sensors thanks to its rechargeable batteries. This research primarily aims to quantify and monitor the functioning and health of animals. Many factors are being considered in this investigation. Research on wild animals, for instance, might involve implanting sensors and cameras all over the environment rather than in the animals themselves.

A WSN is made up of numerous sensors that can collect data, analyse it, and communicate with one another wirelessly. Health is not only the most crucial aspect of our being, but also a major contributor to how efficiently our bodies function. A breakdown in the system could affect people's behaviour and their ability to carry out their regular duties. There appears to be a wide range of causes for people's lack of fitness. Sickness, stiffness, oestrus, mammary tumours, ovarian tumours, displacement antrum, ketosis, extended placental, heifers' diarrhoea, and heifers' sickness are some of the diseases discussed in this article's animal subjects. WSN-based animal monitoring systems receive data about the animal's vitals from sensors implanted on the animal's body, such as the heart rate, breathing rate, and pulse rate. Meanwhile, sensors in its environment report data such as water pollution levels, rates of dirt-borne illness, airborne dust concentrations, and relative humidity (Wang Y., Wang Q., Jin S., Long W., and Hu L., 2022).

The Wearable sensing Animal Healthcare Monitoring system requires setup on a web-connected Emulator device or personal computer. The proposed system is a WSN-based animal care management (ACM) platform. It serves a purpose, leaves a minimal imprint, and is eco-friendly. In these cases, ACM is utilised to manage the general well-being of the animal. The animal's physical characteristics will be gleaned by AHM's array of sensors. The Animal Condition Monitor (ACM) uses sensor data to quickly determine the animal's health status. This is accomplished by performing calculations with the collected sensor data. This aids the health of wild animals and makes it easier to identify any illnesses they may be suffering from. Data would be transmitted using SHMs, and IoT gadgets would propel the industry forward (Jiang Q., Zhang Y., Bao F., Zhao X., Zhang C., Liu P., 2022). Reference: (Jiang, Q., Zhang, Y., Bao, F., Zhao, X., Zhang, C., Liu, P., and Zhang, C., 2022). The frequency of animal health checks is crucial in determining whether or not the animals are at risk from natural disasters like floods and fires. Because of this, determining an animal's tracking ability with this model is straightforward. Because of their poor eyesight, animals often struggle to judge distances accurately. Because of this, you should defend them by making a lot of noise and acting as a group, just like animals do.

II.Related Work

Lameness is a common health problem in the cattle industry, and it hurts not only the animals' well-being but also the number of animals that can be sold. When there are painful problems with the way an animal moves, it changes its gait and posture to lessen the pain. Sprecher D., Hostetler D., and Kaneene J. [8] say that lameness in cattle makes it hard for them to move around, which leads to less milk production, less fertility, and a higher rate of culling. Because of this, it is the third most expensive health problem in the dairy industry, behind problems with reproduction and mastitis [9]. Lameness hurts not only the health of the animal but also its ability to produce and make money. Because it happens so often on farms, lameness is seen as a big health and money problem in modern cow farming. This is one reason why raising cattle in the modern world works so well. Because of this, it is very important to find the cause of lameness quickly and correctly [10]. But the cause and frequency of lameness depend on how the farm is run (pastures and barns) and how the animals are raised.

Manually diagnosing lameness can be done by looking at the changes in behaviour that lame animals show when they walk, such as slowing down, changing their pace, arching their backs, and lowering their heads [11]. Also, as the number and number of cows a farmer raises, he or she usually has less time to do manual lameness exams. This is because raising cattle tends to take a lot of work. Several studies have been done on the health and behaviour of cattle, and the results of these studies have been written up. These studies give reliable information about cows' health and welfare, such as how long they spend grazing, which is an important behavioural trait for the owner to know in order to decide if the food they are given is enough, which in turn affects the cows' output and welfare. The number of health monitoring systems for cattle that have been reported is the number that has been written about. These systems are used to figure out how to find a wide range of cow health-related factors. Using these devices, it's easy to figure out what's wrong with a person based on their rumination, temperature, humidity, heart rate, and the temperature of the area around them [12]. This can be done remotely by deploying wirelessly through nodes to send alerts for anything out of the ordinary, such as important changes in body temperature or early signs of illness.

Quickly figuring out why a cow is lame is important for treating the problem in a way that works and doesn't cost too much and for preventing future diseases [13]. Lameness in cattle is a serious problem that makes them less productive and hurts many farms. In the meantime, the way cattle act is a very important sign of how healthy and happy they are [14]. This has an effect on how many cow products there are and how good they are. Traditional ways of diagnosing lameness and figuring out what's wrong with a horse's behaviour, on the other hand, take a long time and a lot of work. This makes a lot of problems for farms. In this section, we will focus on intelligent perception and analysis technologies that can be used for two main tasks: 1) diagnosing lameness and 2) recognising and judging how a cow acts. In this work, we will look at the possibilities and challenges of future research, as well as the chances of making progress. We will also summarise and analyse previous work in the same areas. Using WSNs, it is now possible to find out if animals are in the pasture and how long they stay there. Controlling the quality of the interior environment is important for the health and well-being of cattle because it has a direct effect on both the amount of output and the quality of that output. Maintaining good ventilation in the stables is important to reduce the risk of long-term, dangerous exposure to ammonia, which can lead to more stress, worsening health, and less production. Huircan et al. [15] came up with a way to keep track of cattle using Zigbee and a localization strategy in WSN.

GUO Songtao (2017) Ecologists need to know how animals react to changes in their environment. Networked sensor technologies can be used to measure the environment and animals with a high level of accuracy so that wildlife can be tracked, studied, and protected. This article looks at traditional ways to find animals, how the Internet of Things (IoT) works and what it can be used for in animal ecology, and the pros and cons of IoT. The

IoT's theoretical limits in animal ecology are also talked about[16]. Even though IoT is a new way to study animal ecology, more research is still needed to develop it as a theoretical framework and apply it to the right scientific frameworks. 2017 Asuka Noda was born in Japan. To make room for grazing animals in vineyards, people who take care of animals need more help with their jobs. As part of this help, the location and behaviour of an animal, especially where it eats, must be tracked and trained. With this kind of system, sheep could safely graze in places like orchards and vineyards. This points to an IoT-based system for keeping track of how animals act. It uses an IoT local network and a cloud platform that can process and store data to collect data from animals and automatically move sheep through vineyard regions. The cloud platform also has machine learning features that make it possible to find useful information in the IoT network's data. So, along with a description of the platform, there are also some outcomes related to the machine learning platform. In particular, this technology was tested to find and diagnose posture-related disorders in animals, and early results look good[17]. This includes a review of the algorithms that were tested, since there were more than one.

Animal monitoring has been the focus of a wide range of written works, each of which had a different goal. Some examples are the study of the migratory behaviour of wild animals [J. Hunter,2013], the behaviour analysis of grazing animals [L. A. Gonzilez, G. J. Bishop-Hurley, R. N. Handcock, and C. Crossman,2015; M. L. Williams, N. Mac Parthaliin, P. Brewer, W. P. J. James, and M.t rose,2016; R. Dutta,2014], the study of grazing site profiles, the animal posture behaviour or the animal estrus [18]. Few researchers do streaming analysis; most of their time is spent using sensors to record animal behaviour for later analysis. Williams et al. used machine learning techniques to look at the GPS traces of forty cows to figure out how they grazed over the course of four months. In their tests, they used the WEKA data mining suite and ran four different machine learning (ML) algorithms. They were able to tell the difference between walking, resting, and eating grass. Because only one sensor is used to track where an animal is, the data is not very accurate, especially when the animal is eating or sleeping. Even though problems have been found with the system's high energy consumption due to the use of GPS receivers, the finds that the animal monitoring mechanism is good for a number of uses related to monitoring animal activity and predicting animal illness[19].

Estrus detection is one of the animal monitoring use cases that has been looked into the most. This may be because managing inseminations well can be good for business. In the studies that were written about here, accelerometer sensors were often attached to the cows' legs or necks to measure how active they were. The information that was collected is then analysed. This lets the peaks of activity that show when an animal is in estrus be found. In addition to the research done in universities, there are also commercial devices [20] that send monitoring information over a wireless network. These systems let you look at eating, ruminating, and activity levels from a distance, which makes managing cows much easier. In the study that Dutta and his colleagues did, monitoring collars were put on the cows. These collars measure the cows' tri-axial acceleration and magnetic field. ML algorithms evaluate individual classifiers like "Binary Tree" and "Naive-Bayes" or groups of these classifiers to set thresholds that are then used to distinguish between activities. Then, these thresholds are used to figure out which activities go in which categories. Even the more simple individual classifiers, like the "Binary Tree," have more than 90% accuracy and sensitivity for some of the activities that have been categorized[21].

RFID and WSN technologies are used in the cattle business to keep track of what each animal looks like and where it lives. They are also used to track the breeding history of animals. RFID-based WSNs have also been set up to track the health of animals. Researchers have used wireless RFID technology to automatically figure out the animals' physiological and behavioural activities in order to keep track of their health. Body temperature is a good indicator of an animal's overall health. It can be used to measure how stressed an animal is [Silanikove N., 2000], figure out the effect of shearing, and spot diseases and disorders early on [22]. Arfuso F. Rizzo M. and Giannetto C. (2016) found that the temperature of an animal's rectal area changes as it ages. In the modern world, the system for taking care of animals' health has changed in a number of ways. Most of these systems can only monitor the health of the animals and send alerts to the farmers through an SMS notification system or an internet of things dashboard like ThingSpeak. All of these things can lead to bad health. Because of this, it is very important to catch diseases and infections early and keep collecting data on animals consistently.

III. Cow Hoof Diseases

A. Limping or lameness is a prevalent clinical manifestation of bovine hoof ailments. The aetiology of this condition could be attributed to a physical trauma, such as an incision or perforation, or a microbial invasion, such as foot rot or digital dermatitis. In the event that a cow exhibits signs of lameness or limping, it is crucial to conduct an examination of the impacted hoof and, if deemed necessary, seek veterinary intervention.

B. Swelling or inflammation observed in the vicinity of the hoof may indicate the presence of infection, injury, or other underlying conditions. The affected region may exhibit concomitant sensations of warmth or discomfort. Hoof swelling in bovine species can be attributed to prevalent factors such as foot rot, abscesses, and injuries. Swelling can serve as an indicator of a potentially severe ailment, such as laminitis, in certain instances.

C. An irregular shape of the hoof is considered abnormal in cattle, as the hooves are expected to exhibit a uniform and symmetrical structure. The presence of misshapen or uneven hooves may suggest the existence of an issue. The anomalous configuration of hooves can be attributed to diverse factors such as genetic predisposition, inadequate nourishment, and physical trauma. In the absence of proper medical attention, this condition may result in impaired mobility and other associated complications.

D. The presence of cracks or fissures in the hooves may indicate desiccation or injury, necessitating intervention such as trimming or therapy to avert subsequent complications. There are several causative factors that can lead to their occurrence, such as overabundance of moisture, physical trauma, or insufficiency in essential nutrients. Cracks can, in certain instances, serve as an indication of a more severe ailment, such as laminitis.

E. Hoof lesions or ulcers may indicate infection or other underlying conditions, and thus necessitate veterinary intervention. The aetiology of such conditions may stem from diverse sources, such as bacterial or fungal infections, physical injuries, or inadequate nutrient intake. In the absence of medical intervention, the presence of lesions and ulcers may result in the development of lameness and various other complications.

F. Excessive wear of a cow's hooves may suggest an underlying issue with the cow's gait or hoof structure if the hooves are wearing down too rapidly or unevenly. There are several factors that can contribute to excessive wear of hooves, such as inadequate hoof care, insufficiencies in nutrition, and physical trauma. If not addressed, this condition may result in lameness and other associated issues.

G. Foul odor: The presence of a noxious scent emanating from the hooves may indicate the presence of an infection or other maladies, necessitating the intervention of a veterinary professional. It is plausible that it could be concomitant with additional symptoms such as edoema, elevated temperature, or exudate. Foul odour in cows can be attributed to various factors such as bacterial or fungal infections, foot rot, and digital dermatitis. In the absence of proper medical attention, these ailments have the potential to result in impaired mobility and additional complications.

IV. Proposed System

As a result, one of the primary goals of this research was to conduct an analysis of the various methods for the deployment of accelerometer sensors, with a particular emphasis on the possibility of using cow neck tags. The device has been mounted on the cows neck, it will not affect the regular life of cow. Also the front leg, the collar, and the ear were the three different deployment sites on the cow that were tested. This section gives a description of the procedures that were utilised for attaching the X16-mini and AX3 devices to each deployment site as well as the orientation of the sensor axis. The axis orientations of each deployment point were identical, and this orientation was treated as a constant across all of the trials. Although the orientation of each axis has no effect on the measurements produced by the sensors, it is essential that this information be understood in order to properly interpret the data. The dorso-ventral, lateral, and anterior-posterior orientations of the X, Y, and Z axes are shown in Fig. 1. The position of the cow has been determined by this research CPx, CPy and Cpz. The accelerometer data which is stored in the memory card and thingsboard dashboard. Based on this data we have to trained and testing the machine and it will give the prediction.

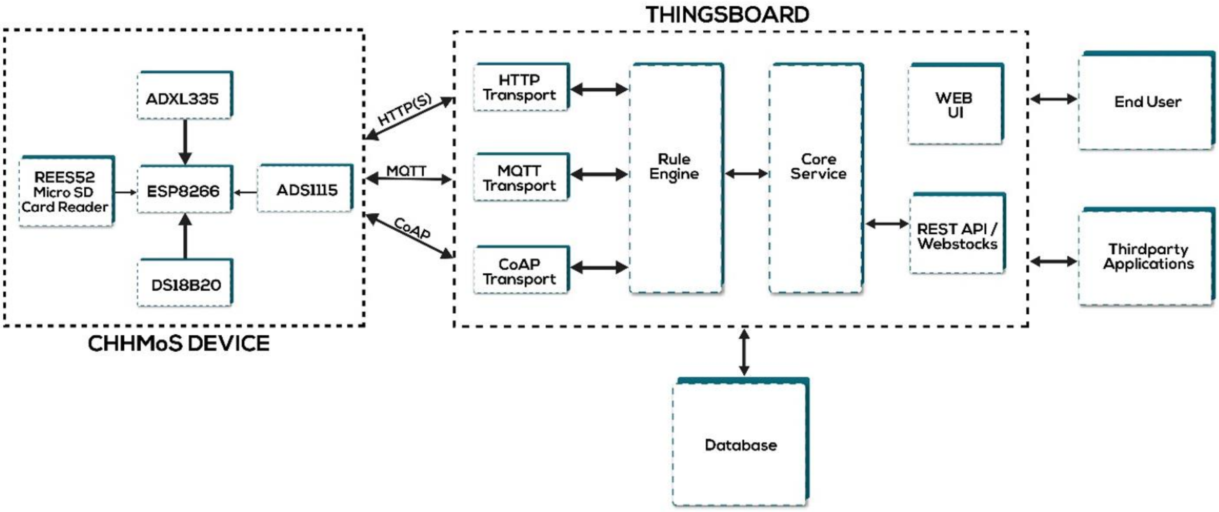


Fig 1. CHHMoS Architecture

The four sensors [ADXL335, ADS1115, REES52 and DSI8B20] have been connected to ESP8266, called 'Cow Hoof Health Monitoring System Device. The CHHMoS device has been connected to Thingsboard through the internet. The CHHMoS Device has been mounted around the cow's neck collar, and this facilitated collecting all the data regarding the cow's movement and health and then transferring it to Thingsboard via Wifi. Eventually, all of the cow's data became accessible and available on Thingsboard. Because of this process, we can easily monitor the cow's movement and health.

```
cowhoof_healthTTT
#include <ESP8266WiFi.h>
#include <DHT.h>

const char* ssid = "YourWiFiSSID";
const char* password = "YourWiFiPassword";

const char* apiEndpoint = "https://yourserver.com/api/data";
const char* apiKey = "YourAPIKey";

DHT dht(D4, DHT22); // Assuming D4 pin is connected to the dat

void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
```

Fig 2. CHHMoS Arduino Code

Fig. 2 shows the Arduino Code of the cow's hoof health monitoring. It helps to connect the Node MCU ESP8266 to thingsboard. After the sucessul compilation, the code has been embed to the device and it has been connected through WIFI. So the user has been monitor the actual data of cow position, health, temperature.

V.Results And Discussion

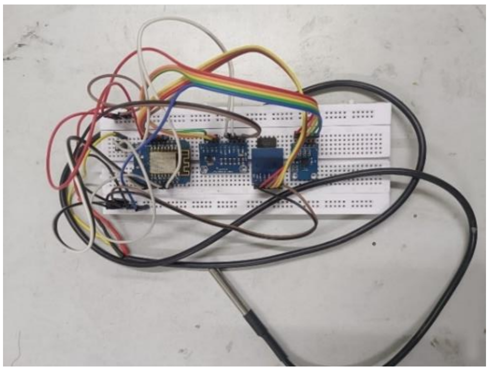


Fig 3a. CHHMoS device before soldering

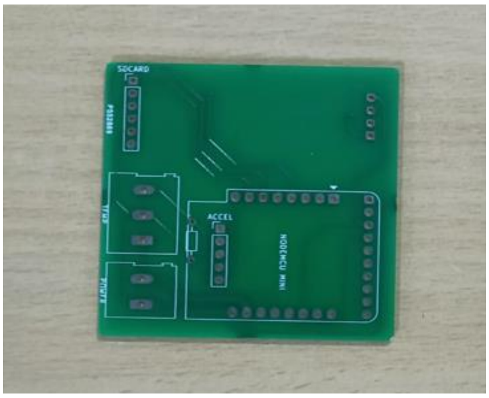
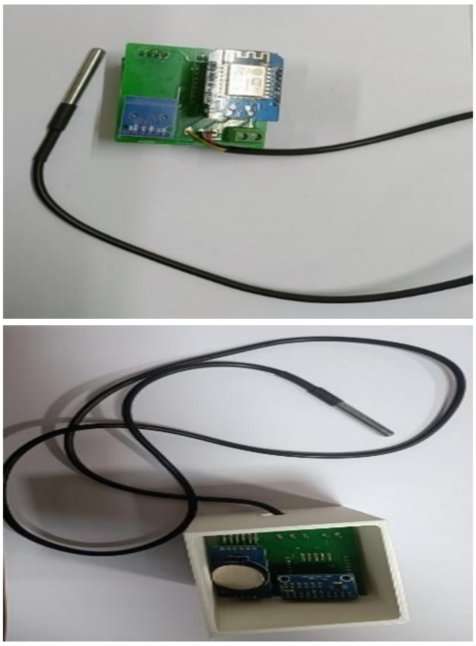


Fig 3b. PCB board of CHHMoS

The above Fig. 3a shows that; before the making of the CHHMoS device, all the sensors were connected to the breadboard for testing purpose. Fig. 3b above shows that the figure2 have been made above PCB board after successfully testing the device.

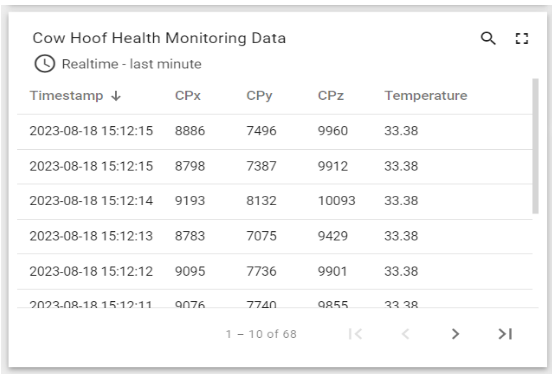


(a) (b)

Fig 4. Circuit of CHHMoS

Fig. 4(a) and 4(b) show that all the required sensors have been connected under the PCB board. And the complete CHHMoS Device has been packed into the box.

Fig 5. Cow Hoof Health Checking



Timestamp ↓	CPx	CPy	CPz	Temperature
2023-08-18 15:12:15	8886	7496	9960	33.38
2023-08-18 15:12:15	8798	7387	9912	33.38
2023-08-18 15:12:14	9193	8132	10093	33.38
2023-08-18 15:12:13	8783	7075	9429	33.38
2023-08-18 15:12:12	9095	7736	9901	33.38
2023-08-18 15:12:11	9076	7740	9855	33.38

Fig 6. Actual data from CHHMoS device

Fig. 5 shows the researcher analysing the health condition of the cow's hoof. Using the CHHMoS Device, the above Fig.6. data was displayed on the Thingsboard dashboard. Likewise, we can use these data for Machine Learning purposes.

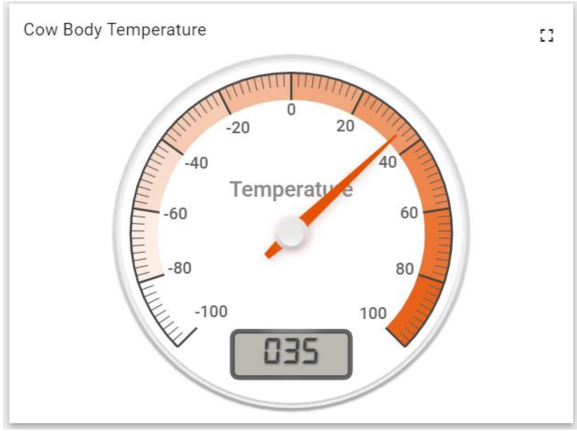


Fig 7. Cow body temperature from CHHMoS device

The above picture Fig.7. shows the cow body temperature displayed on Thingsboard dashboard. The CHHMoS Device captures the data with its real time; that is, the same time which is displayed on the device monitor while collecting the data from the hoof will be displayed when it is uploaded on Thingsboard.

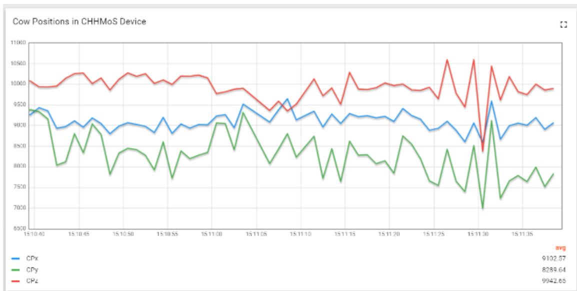


Fig 8. Cow position from CHHMoS device

The graph Fig.8., which is seen on the device monitor as demonstrated in the illustrated graph picture, displays the position of the cow (CPX,CPX and CPZ) as it changes. Based on the cow's walking position, we can identify the cow's type; a normal or a lame cow.

A. Calculating the Metrics

The following characteristics were computed with either a 5 or 10 second epoch duration depending on the situation. The average value of the acceleration along the X axis during the course of the period is denoted by the symbol "CPx"

$$CPx = \frac{1}{T}\sum_{t=1}^{t} x(t) \qquad \text{Eqn. (1)}$$

Average Y-axis (CPy): The average value of the Y axis acceleration over the epoch.

$$CPy = \frac{1}{T}\sum_{t=1}^{t} y(t) \qquad \text{Eqn. (2)}$$

Average Z-axis (CPz): The average value of the Z axis acceleration over the epoch.

$$CPz = \frac{1}{T}\sum_{t=1}^{t} z(t) \qquad \text{Eqn. (3)}$$

Where T is the total number of counts in the epoch.

According to Hokkanen et al. [17], the mean values give information on the direction in which the movement is occuring. Movement Variation (MV): According to Campbell et al. (2013), MV is the entire amount of variation that exists inside the signal epoch and may also be referred to as waveform length. MV is calculated by taking a cumulative measure of the acceleration's amplitude, frequency, and duration. Put another way, MV is a measurement that determines the overall amount of variation that a signal's vibration experiences in all three dimensions [18]. Variance is a measure that may be used to get information about the overall amount of movement.

$$MV = \frac{1}{N}\left(\sum_{i=1}^{N-1}|X_{i+1} - Xi| + \sum_{i=1}^{N-1}|Y_{i+1} - Yi| + \sum_{i=1}^{N-1}|Z_{i+1} - Zi|\right) \qquad \text{Eqn. (4)}$$

where N is the total number of records in the epoch.

Conclusion

Monitoring a cow's health is very difficult nowadays, but using the CHHMoS Device can make the job very easy. So far, the dairy farms are increasing in number systems are the inevitable part of human beings nowadays. These days, it will be more practical to keep the efforts small and done in a short period of time. What usually takes hours to be done by a human effort can be replaced with sophisticated devices, and the CHHMoS Device is a good example of how easy to monitor a cow's health with less effort and more specificity with a simply mounting the device around the cow's collar. This paper has provided, with illustrative figures, how the entire monitoring process can be completed effectively and professionally and transferred to Thingsboard via the use of internet Wifi.

Acknowledgement

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