CattleCare: IoT-Based Smart Collar for Automatic Continuous Vital and Activity Monitoring of Cattle

Kadali Umesh Chandra
IIIT Naya Raipur, India
Email : kadali21102@iiitnr.edu.in

Rapolu Shiva Teja
IIIT Naya Raipur, India
Email : rapolu21102@iiitnr.edu.in

Siri Arelli
IIIT Naya Raipur, India
Email : siri21102@iiitnr.edu.in

Debanjan Das
IIIT Naya Raipur, India
Email : debanjan@iiitnr.edu.in

Abstract—**Farm productivity is increasing these days drastically due to farm automation and new technical procedures. The cattle health monitoring system is a current research topic in agricultural automation. However, most of them focus on health parameters and do not include the feedback system. This paper proposed an IoT-based CattleCare platform for both vital and activity monitoring of the cattle. The Cattle Activity Prediction algorithm classifies the activities of cattle in order to keep track of behavioral changes in cattle as well as their health parameters. The system algorithm can predict cattle activity like grazing, stationary, or walking with an accuracy of 91.46%. The sickness of the cattle can be observed by the change in its behavior for that it is really important to keep track of its activities. This model has stages like data collection, storage, analysis, prediction and feedback. With the advancement in technology and the existence of the internet, we can practically connect any device to the internet and implement the concept of IoT.**

Index Terms—**Farm automation, Health parameters, Feedback, Cattle Activity Prediction algorithm**

I. Introduction

The cattle sector is vital to the global economy. Animals like cows, buffaloes, sheep, goats, and others are crucial to rural life. Around 50% of India's population are employed in the field of agriculture and animal husbandry [1]. Farmers are suffering severely as a result of a variety of diseases that are affecting the farm's animals. However, farmers must devote more time and resources to constant monitoring. Farmers cannot entirely rely on their ongoing visual observations since new animal health disorders are emerging that are difficult to prevent. In order to solve this issue, the outdated methods of monitoring cow health must be replaced with more modern ones. To aid local farmers, an intelligent method of cow health monitoring must be developed. In order to understand animal behaviour and track biological reactions, precision livestock farming techniques are integrated with the most recent digital technology. The automated systems for checking up on the health of cattle are especially super beneficial for dairy farms in rural sections of the nation where the availability of doctors is limited.

Manual supervision is used in the traditional method of livestock monitoring, needs a lot of skilled labour and time [2]. Therefore, it will be preferable to automate the monitoring of cattle in a cost-effective manner so that their lifespan may be increased. For this different types of sensors are to be used [2], [3]. Regular human-cattle connection has all but disappeared as a result of the expansion of dairy farms, which has led to the automatic milking systems that are replacing traditional milking methods. A farm-level analysis of the health, welfare, and comfort of dairy cattle can be done by observing their behaviour. Certainly, behavioral changes are obvious warning signs of welfare and health issues with cattle. Consequently, these may be included 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 movement is crucial for monitoring and managing their behavioural patterns and activities in order to gather data on their productivity and health. As a result, various techniques for monitoring behavioural changes, including precise sensing and smart processing, have become crucial for the herd's survival.

There are different IoT applications that are being used in the field of health monitoring fields like integrated health monitoring system, using Arduino and LabVIEW technologies movement monitoring of cattle, non-invasive sensor technology [5], [6], [7]. The existing methods or techniques mainly focuses on

- Sensors: They use various sensors for getting data about various parameters which makes the sensor node more complex. They don't mention or propose about building the sensor node in an understandable way.
- Disease: The main aim of many proposed systems is to detect particular disease using the sensor information.
- The end user can't access the cloud or they are not notified on time.

The proposed system is cost effective and successfully tracks the health parameters of the cattle and its activity for every short intervals of time so that the cattle owner can know what his/her cattle is doing and it also shows the visualization for what duration of time the cattle is doing each activity so that if there is any activity that is less its usual duration of time, the farmer can understand that his/her cattle is suffering with health problem.

II. Related Works

IoT based healthcare is one of the important topics and is a revolutionary technology allowing the huge production of the innovative technology making them to be adopted by a large number.

The following are some drawbacks of current models:

Farmers are uninformed when the cattle are suffering from sickness. There are numerous diseases that harm cattle. Farmers are unaware when their cattle are infected with a disease since they are not notified if there is an unusual change in the health of the animals. As a result, the farmers are unable to cure the cattle at the right point, perhaps worsening the sickness. The current procedure takes a lot of time. When compared to an automated method, this process takes longer because farmers must physically inspect the animals to determine whether they are infected with any diseases. In [5], the author has used Arduino UNO to measure the cattle body parameters and uses LabVIEW to view real-time graphical representations of the signals. In [16], the author has proposed a system in which health parameters are taken into consideration and a piezoelectric sensor is used that will respond when cattle feels weak and informs the doctor but when coming to heartbeat, it will also increase when the cattle has done much work, but the doctor thinks that the cattle is unhealthy which is wrong in this case. If the activity of the cattle is known at the time then we can find that the raise in heartbeat is due to excessive work or tiredness of cattle. In [[17], there is an analysis for which different diseases can effect their cattle, but their activity is not taken into consideration. Heartbeat is one of the most important factors that needs to be taken into consideration while checking the health parameters which is missing in [7]. There is less accuracy in [10], [12], [14], [15], as there is no decision making model. Sometimes, though the health parameters like, Body temperature, Respiration, Humidity, Heartbeat and Rumination are fine, the cattle might feel weak due to inner health problems that cannot be known by just knowing the external health parameters. But we can get a rough idea whether it is good or not by observing its activities. In [13], only one health parameter i.e., only temperature is taken into consideration. Only rumination activity can be predicted in [8], but other activities are not predicted. Most importantly all the above mentioned works did not focus on making a collar belt so that data could be collected continuously for analysis.

A clear overview of the related research papers has been tabulated in Table I.

TABLE I
COMPARISON OF EXISTING SOLUTIONS

Title	BM	Health Parameters	Limitations
Awasthi *et al.* [7]	Yes	Temperature	Heartbeat
Unold *et al.* [8]	No	Rumination, heart rate, temperature and humidity	Less accuracy as there is no decision making module
Mudziwepasi *et al.* [6]	No	Temperature, heartbeat, rumination	high storage overhead and no decision making module
Mhatre *et al.* [10]	No	Temperature, sweating, heartbeat, and rumination	Less accuracy as there is no decision making module
Sampath *et al.* [12]	No	Temperature	does not consider heartbeat values.
Swain *et al.* [5]	Yes	Temperature, Respiration, Rumination, Humidity, Heartbeat	Less accuracy as there is no decision making module
Park *et al.* [13]	No	Heartbeat, breath rate & momentum	Less accuracy as there is no decision making module
Barriuso *et al.* [14]	Yes	Heat, calving time and levels of feed	More computation & communication cost

BM:Behaviour Monitoring

The main objective of the proposed work are the following:

- Replace existing traditional methods with IoT-based methodology.
- Create a wearable device that monitors the cattle's health using wireless sensor technology.
- Predict the cattle's activities by taking sensor readings.
- Provide a framework designed to alert the owner if any abnormalities are observed in the cattle's behaviour to take quick action.

The proposed solutions are novel and significant in the following ways:

- An automated system is proposed to monitor cattle's health without human intervention.
- Behavioural changes in the cattle are observed by predicting their activities.
- The CAP algorithm is proposed.
- The CAP algorithm predicts the cattle's activities like stationary, walking, and eating.
- Health parameters like temperature and pulse will be monitored using a wearable collar device.

III. The Proposed CattleCare System

This proposed system comprises of three parts namely data collection from sensors, Sending data to cloud and transferring of collected data, Analysis and prediction of data to the user. The sub-sections will be giving a clear view of implementation of the proposed system. An overview of the system is given in Fig 1.

A. Sensor Node

The prototype consists of a 3D-printed case that holds Node MCU, a microcontroller with ESP-8266 as a WiFi module and has high power efficiency, which is very useful in communication with the cloud, DS18B20 Dallas sensor for body temperature, pulse sensor for pulse readings, ADXL345 for acceleration values along the 3 axes, and a powerbank of 10000mAh capacity for power supply as shown in Fig 2.

B. Vital Monitoring

The 3D-printed case will be placed on the neck of the cattle making sure that the pulse sensor touches its nerve to get accurate pulse values. The readings of temperature and pulse

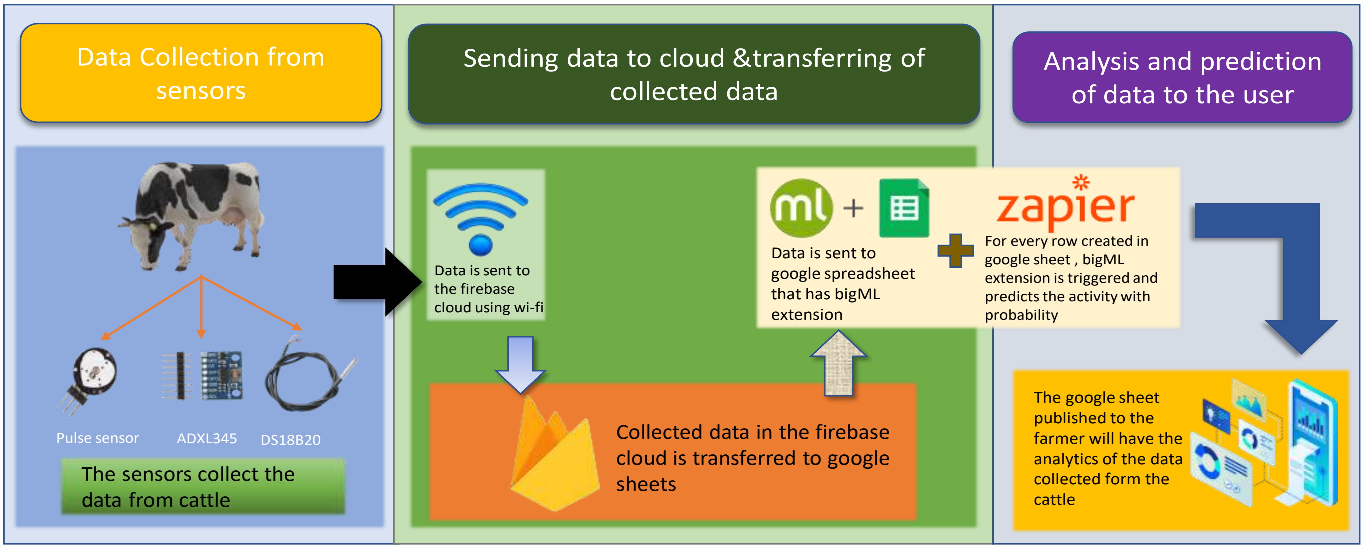

Fig. 1. Overview of the proposed system

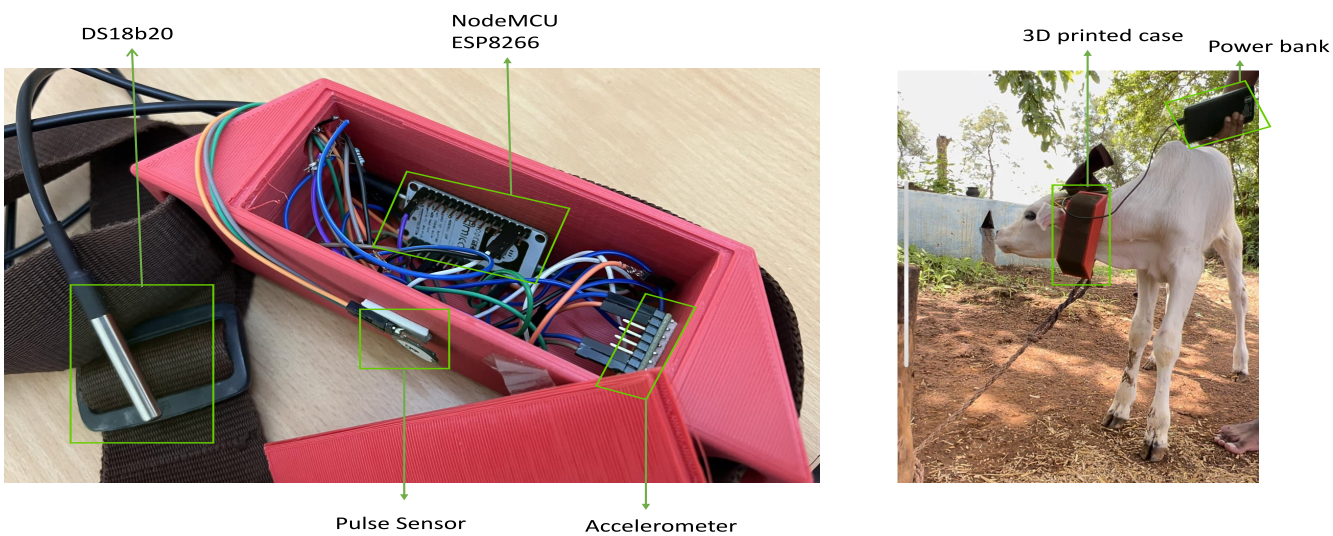

Fig. 2. Components of the sensor node

are sent to google firebase cloud. The data collected by google firebase is sent to googlesheets so that the readings can be shown graphically and if the readings exceed their threshold values, an email will be sent to the cattle owner to make him alert. If the pulse value exceeds the threshold value and the acceleration along y-axis also exceeds more than 3.8, then the email will be sent as the heartbeat rose due to fast movement of cattle. The data that is collected by the firebase cloud will be updated into the google sheets for every 5 minutes. Here we use the threshold values as that of normal body temperature (36°C-40°C) and pulse value (76-96 beats/min) [4] of a cattle.

C. Cattle Activity Prediction

The accelerometer values are sent by NodeMCU to the google cloud for every minute and from there it is sent to google sheet. The activity of the cattle can be predicted by using CAP(Cattle Activity Prediction) algorithm 11. To predict the activity of the cattle we use Machine Learning algorithm - One vs all Logistic Regression with the help of BigML extension which is found in the google sheet. Using this, the ML algorithm will predict whether the cattle is stationary or walking or eating. The activity will be automatically updated into the google sheets whenever a new row is created with help of zapier, a third party application that is used to automate the things whenever a set trigger happens, an action is performed. Here we set the the trigger as creation of new row in google sheet and action as prediction of activity with the help of bigML. The duration of the activity can be calculated by number of times a particular activity is predicted divided by 60 gives the number of hours that particular activity is performed.

The google sheet which contains all the data from the cattle will be shared to the cattle owner through its link.

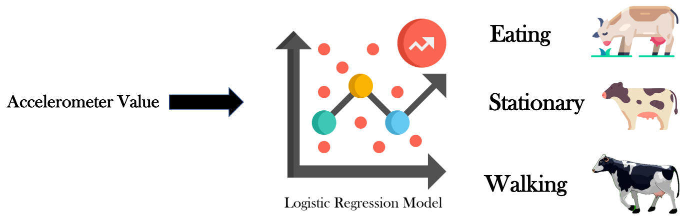

Fig. 3. Activity is predicted from the above classes

D. Preparation of data

The 3D printed case is wound over the neck of the cattle. The dataset was prepared by observing each activity of the cattle for 1 hour daily for 30 days. This dataset was uploaded to the bigML extension in the google sheets. The summary of the dataset collected on a day is as shown in Fig 4.

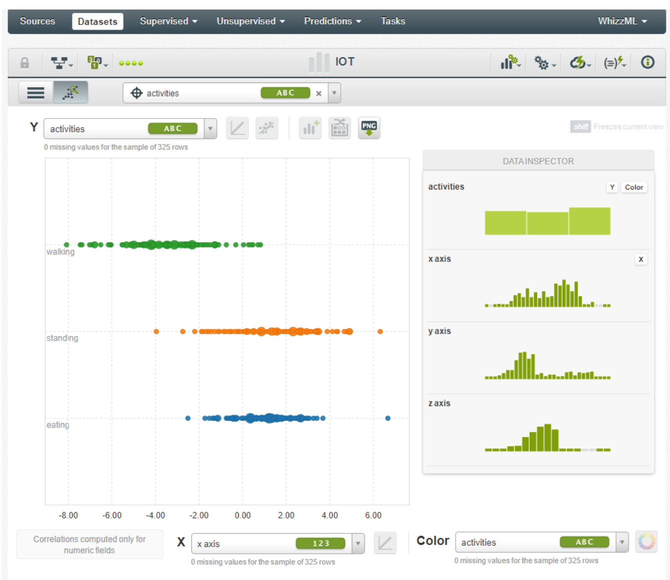

Fig. 4. Summary of sample of the dataset

E. Cattle Activity Prediction algorithm

Let us have a deeper look into what happens in logistic regression in this case:

Logistic regression is a supervised learning algorithm that helps in binary classification by predicting the probability whether a feature set belongs to a particular class or not. If the probability of prediction is greater than 0.5 then the output will be 1 otherwise the output will be 0. In this case we have three classes viz.,eating, stationary, walking. As logistic regression is used only for binary classification we use one vs all i.e., the algorithm finds the probability of each of the three classes against the remaining two and predicts the activity as the one which has the highest probability. To find the probability of an activity the algorithm uses a logistic function,

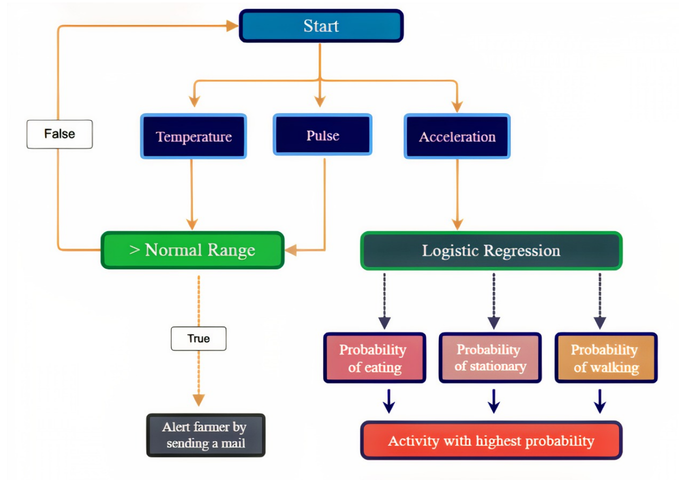

Fig. 5. Proposed CattleCare process flow for health and activity monitoring

$$h_\theta(x) = \frac{1}{1+e^{-x}}$$

The cost function signifies the measure of how wrong the model is, in terms of its ability to estimate the activty (in this case). So it is essential to reduce it to the minimum. Inorder for this to happen, the input training dataset is used in a way so that the cost function is minimum.

Logistic regression cost function:

$$\operatorname{Cost}\left(h_\theta(x), y\right)=\begin{cases} -\log\left(h_\theta(x)\right) & \text{if } y=1 \\ -\log\left(1-h_\theta(x)\right) & \text{if } y=0 \end{cases}$$

The simplified cost function can be written as $J(\theta)=-\frac{1}{m}\left[\sum_{i=1}^{m} y^{(i)} \log h_\theta\left(x^{(i)}\right)+\left(1-y^{(i)}\right) \log \left(1-h_\theta\left(x^{(i)}\right)\right)\right]$
The value of the theta can be known from the input training dataset

The value of the above expression will be calculated for each new row of the accelerometer values for all the three activities and the highest of them will be shown as it will have highest probability and is displayed in the google sheet as shown in the Fig 3.

Algorithm 1 Cattle activity prediction Algorithm

Start
Taking inputs
A = *probability of eating*
B = *probability of walking*
C = *probability of being stationary*
if $A \geq$B and $A \geq$C **then**
    print(Activity = "Eating")
else if $B \geq$C and $B \geq$A **then**
    print(Activity = "Walking")
else if **then**
    print(Activity = "Stationary")

The flow of data from sensors to alerting the cattle owner when temperature and pulse values are above set threshold and predicting the cattle activity is as shown in the Fig 5.

The graphs plotted for each activity is as shown in the Fig 6. These are the observations of the accelerometer values along 3 directions namely x, y and z axes of the cattle during its activities of eating, being stationary and while walking.

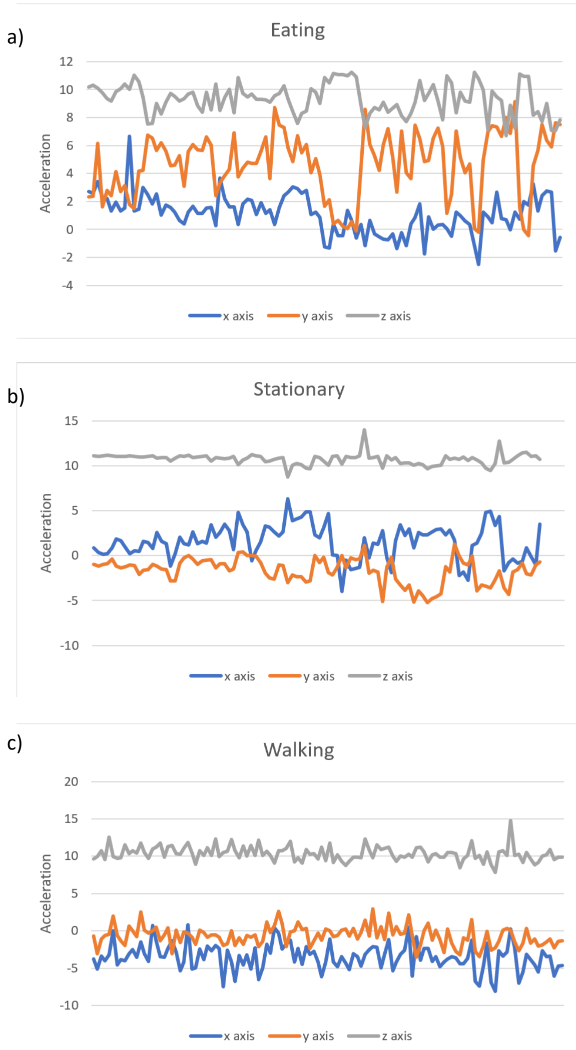

Fig. 6. Acceleration plots for a)Eating b)Stationary c)Waliking along 3 axes

IV. Experimental Results And Analysis

The graphs produced from the readings during field deployment are given in Fig 7. The readings collected from the temperature sensor and pulse sensor are plotted as a graph for clear analysis. The 3D printed case is wound over the neck of the cattle so that the pulse sensor touches to its nerve and the temperature sensor touches to its body in order to get accurate values. The predictions made by CAP Algorithm are also given in Fig 7. These predictions are plotted in the form of bar graph

TABLE II
Comparision with other Algorithms

Algorithm	Accuracy	Precision	F1 score
Logistic Regression	91.46%	0.96	0.92
Support Vector Machine	87.80%	0.95	0.90
K nearest neighbours	89.02%	0.96	0.91

for better understanding of number of hours spent by the cattle in each activity as shown in Fig 9. The experimental results are analysed and presented in the form of confusion matrix shown in Fig 8 for the prediction of activities. The accuracy, precision and F1 scores of the model when predicted using algorithms like SVM and KNN are as shown in the following table II.

V. Conclusion and Future Scope

The final analysis of this paper is that this prototype is easy to use and successfully tracks the health parameters of the cattle and predicts their activity and sends an email to the owner of the cattle if the values of temperature and pulse values are above the set threshold values so that he/she can take proper care of their cattle. This can be further developed by by the following ways:

- Database Management System can be used to store data in a structured manner on a daily basis so that we can have the information of the cattle on any particular day.
- A webpage can be created for the cattle owner can store all the information at one place for each cattlel.
- Using better visualization techniques and tools which is easier to understand.

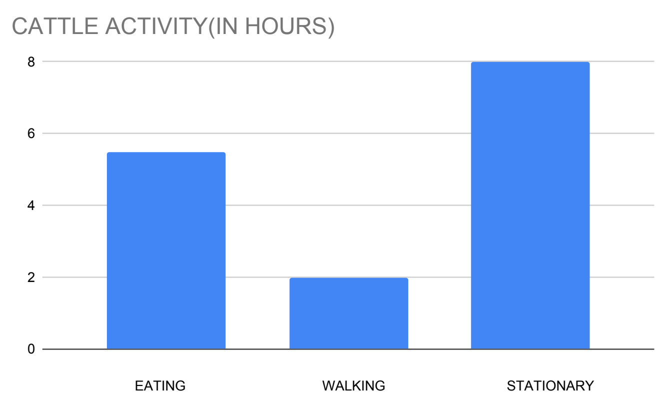

Fig. 9. Bar Plot of Cattle Activity in 15 Hours

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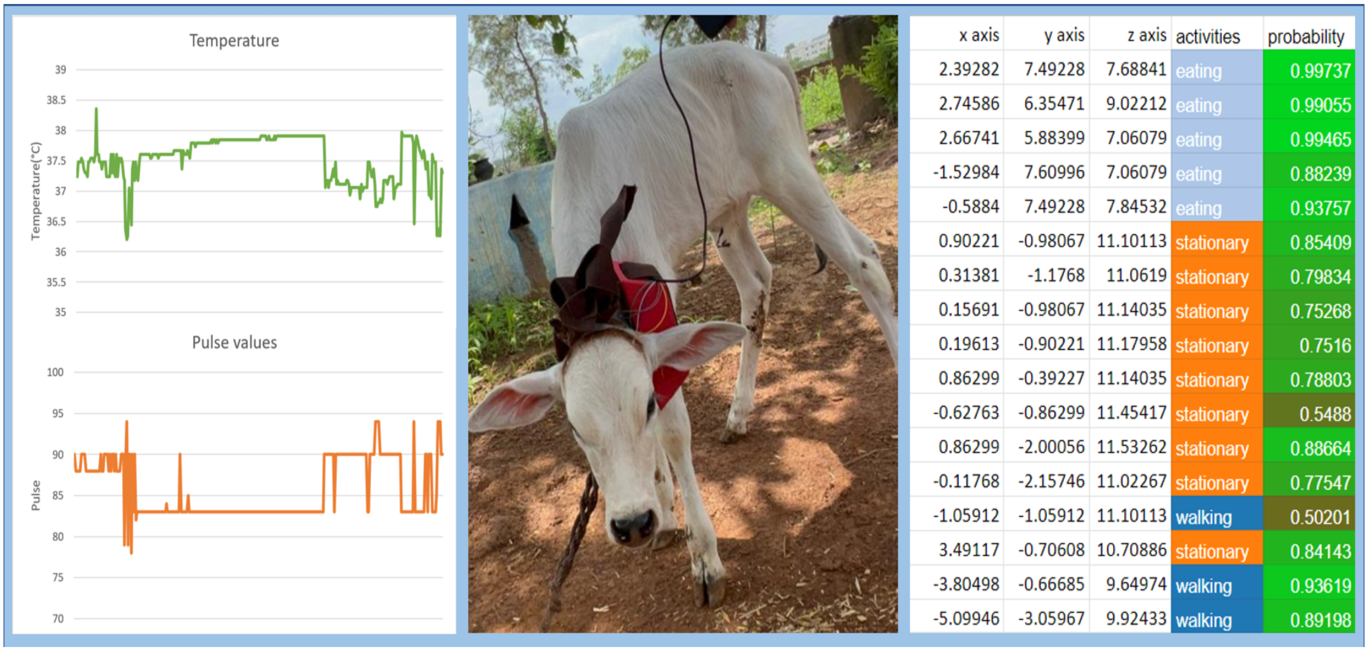

x axis	y axis	z axis	activities	probability
2.39282	7.49228	7.68841	eating	0.99737
2.74586	6.35471	9.02212	eating	0.99055
2.66741	5.88399	7.06079	eating	0.99465
-1.52984	7.60996	7.06079	eating	0.88239
-0.5884	7.49228	7.84532	eating	0.93757
0.90221	-0.98067	11.10113	stationary	0.85409
0.31381	-1.1768	11.0619	stationary	0.79834
0.15691	-0.98067	11.14035	stationary	0.75268
0.19613	-0.90221	11.17958	stationary	0.7516
0.86299	-0.39227	11.14035	stationary	0.78803
-0.62763	-0.86299	11.45417	stationary	0.5488
0.86299	-2.00056	11.53262	stationary	0.88664
-0.11768	-2.15746	11.02267	stationary	0.77547
-1.05912	-1.05912	11.10113	walking	0.50201
3.49117	-0.70608	10.70886	stationary	0.84143
-3.80498	-0.66685	9.64974	walking	0.93619
-5.09946	-3.05967	9.92433	walking	0.89198

Fig. 7. Graphical plot of Sensor Readings

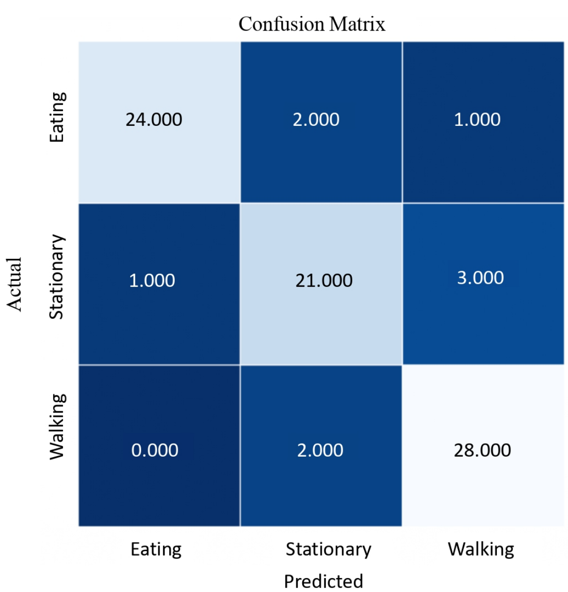

Fig. 8. Confusion Matrix for the activities predicted

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