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Deployment of an intelligent and secure cattle health monitoring system

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Corresponding Author:	Jehangir Arshad COMSATS University Islamabad - Lahore Campus PAKISTAN
First Author:	Jehangir Arshad
Order of Authors:	Jehangir Arshad
	Talha Ahmad Siddiqui
	M. Ismail Sheikh
	M. Sadeed Waseem
	M. Abu Bakar Nawaz
	Ateeq Rehman
	Elsayed Tag Eldin
Abstract:	Wireless Sensor Networks (WSNs) are revolutionizing the globe with their sensing technologies. This initiative aims to design and deploy a cattle health monitoring system (CHMS) for the agriculture sector for the well-being of livestock and the eradication of hunger. The production and consumption of all dairy and meat products can only be conducted responsibly if the health of the source animal is protected. In this regard, WSNs, a component of the Internet-of-things (IoT) system, can be utilized for monitoring cow health due to their adaptability and portability, which enables them to be applied to expansive domains such as cattle healthcare. The integration of IoT and artificial intelligence enables the prediction of livestock illnesses. The primary purpose of this proposed system is to forecast cattle diseases utilizing real-time data from non-invasive body-area sensors and Artificial Neural Networks (ANN) and to display the expected results to authorized personnel via a web application. Popular authentication schemes are used in this system as it is susceptible to hacking and requires robust network security to protect the confidentiality, integrity, and availability of its resources. The working of this system is novel. The performance of the proposed system was measured to be approximately 98 percent. CHMS will assist concerned farmers in remotely monitoring the health of their livestock from a variety of locations and in taking appropriate and timely measures to protect animal health. Technological automation will lower prices and labor inputs while enhancing farm output.

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Deployment of an intelligent and secure cattle health monitoring system

Jehangir Arshad[1], Talha Ahmad Siddiqui[1], M. Ismail Sheikh[1], M. Sadeed Waseem[1], and M. Abu Bakar Nawaz[1], Elsayed Tag Eldin[2], Ateeq Ur Rehman[3]

[1]Department of Electrical & Computer Engineering, COMSATS University Islamabad, Lahore Campus, Lahore 54000, Pakistan
[2]Faculty of Engineering and Technology, Future University in Egypt New Cairo 11835, Egypt
[3]Department of Electrical Engineering, Government College University, Lahore 54000, Pakistan

Corresponding author: Jehangir Arshad (e-mail: jehangirarshad@cuilahore.edu.pk).

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Deployment of an intelligent and secure cattle health monitoring system

ABSTRACT Wireless Sensor Networks (WSNs) are revolutionizing the globe with their sensing technologies. This initiative aims to design and deploy a cattle health monitoring system (CHMS) for the agriculture sector for the well-being of livestock and the eradication of hunger. The production and consumption of all dairy and meat products can only be conducted responsibly if the health of the source animal is protected. In this regard, WSNs, a component of the Internet-of-things (IoT) system, can be utilized for monitoring cow health due to their adaptability and portability, which enables them to be applied to expansive domains such as cattle healthcare. The integration of IoT and artificial intelligence enables the prediction of livestock illnesses. The primary purpose of this proposed system is to forecast cattle diseases utilizing real-time data from non-invasive body-area sensors and Artificial Neural Networks (ANN) and to display the expected results to authorized personnel via a web application. Popular authentication schemes are used in this system as it is susceptible to hacking and requires robust network security to protect the confidentiality, integrity, and availability of its resources. The working of this system is novel. The performance of the proposed system was measured to be approximately 98 percent. CHMS will assist concerned farmers in remotely monitoring the health of their livestock from a variety of locations and in taking appropriate and timely measures to protect animal health. Technological automation will lower prices and labor inputs while enhancing farm output

INDEX TERMS Artificial neural network, cattle health monitoring, multi-class classification, IoT, livestock, message queuing telemetry transport protocol, security, two-factor authentication, wireless sensor networks.

I. INTRODUCTION

Wireless sensor networks (WSNs) have evolved in healthcare based on low-networked technologies and medical sensors as they are the most modern technologies and are more favorable than conventional systems [1]. This is because data transmission between nodes in a mesh-based architecture network uses less energy Due to a growing population; demand for dairy products is expanding fast, leading to greater cooperation between the dairy sector and academic institutions to achieve the UN's Sustainable Development Goals (SDGs) (UN) [2]. Livestock farming helps individuals in emerging countries like Pakistan as it boosts their standard of living and leads to financial progress. In 2019, Pakistan produced 47 million tons of milk [3]; the third most in the world but farmers in Pakistan face huge financial losses owing to a lack of technology and rapid climate changes. This affects the production of dairy products and healthy meat, which affects the economy and finance [4]. Therefore, the livestock farming sector must employ the newest technology to monitor and regulate livestock herds. Farm scientific technologies must be used to monitor cattle health to reduce production costs and battle diseases.

This study covers a wireless cattle health monitoring system that uses advanced technologies to monitor continuous cattle’s health data, predict early diseases using artificial neural networks, and secure the WSN against any intrusions. WSN will allow the farmer to take intelligent

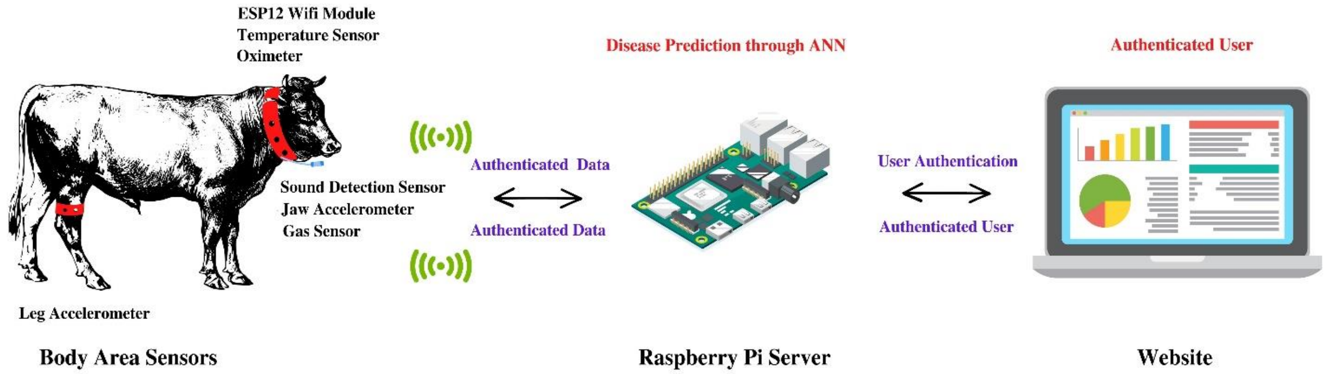


FIGURE 1: System overview diagram of the system.

and accurate precautions to avoid any loss [5]. This solution will include a reliable authentication scheme to guarantee only trustworthy nodes send data to the base station [6]. This ensures the authenticity and transportation of sensor data to the base station. Using an artificial neural network on real-time data will allow us to predict diseases. This information will also be provided on a web-based application for end-users to monitor cattle behavior. Only users who have authenticated can access this information.

This paper is organized as follows: Section II provides the literature review of different health monitoring systems. Section III presents the IoT-based livestock infrastructure consisting of three layers i.e. physical layer, network layer, and application layer. Section IV presents the research issues and the challenges. Section V presents the future research directions. Lastly, the article has been concluded in section VI.

II. RELATED WORKS

Wireless Sensor Networks have piqued the interest of technological and scientific research organizations. Sensor-based automatic health monitoring is essential to follow the individual animal movement and monitor the health conditions [5, 7]. WSNs are a low-cost solution for identifying cattle illnesses. An advanced automated farm will improve output by reducing human intervention since continuous monitoring needs more resources and time. Constant visual surveillance by farmers isn't entirely accurate since animal health issues are complicated to detect without proper tools. WSNs enable continuous welfare monitoring easier with more robustness than manual observation.

Several external sensors, such as heart rate, accelerometer, pedometer, and vibration sensor, have been designed to solve animal health issues [8]. Automated approaches are utilized to diagnose metabolic issues in cattle. Cattle have tags or collars on their necks that provide information. The microphone is placed in a plastic device on the head collar's left side dorsally [9]. A complex algorithm is used to assess tag noise.

Handcock et al. presented a satellite, WSN, and GPS animal monitoring system and its ecological impact. Animal landscape interactions were created using satellite pictures and ground-based sensors [10]. Nadimi et al. designed a ZigBee-based animal monitoring system. The authors used a single-hop 2.4-GHz WSN to measure dairy cow motion. WSNs address animal behavior and pasture time [8].

According to many researchers, healthy and sick cows behave differently when lying, standing, and feeding. González et al. discovered differences in short-term feeding behavior when ketosis and chronic lameness first occurred [11]. Another health monitoring method for cattle was introduced by Smith et al., where cardiovascular, respiratory, and head movements were all monitored [12]. The system is built on a turn microcontroller board on an AMD186 processor. Changes in rumination and feeding behavior in cattle could be indicators of health issues. The Rumi Watch System (RWS) is a sensor-based instrument that monitors dairy cattle's fundamental activities [12]. The device uses a pressure sensor to track the cow's jaw movement

Using a 2.4 GHz frequency-based communication module, Nadimi et al. presented ad hoc WSNs-based monitoring and classification of animal behavior [8]. This system can provide communication consistency, low packet loss, and low energy consumption. Using a multi-layer perception-based artificial neural network, behavioral parameters are converted into behavioral modes.

Convolutional Neural Network (CNN) employs accelerometer collars to identify cow activity (rumination, feeding, and other) [13]. 18 steers were examined for raw acceleration during three farm trials in the UK (Easter Howgate Farm, Edinburgh, UK), using muzzle-mounted pressure sensor halters providing ground truth data. Various neural network topologies are studied and hyper-parameter searches optimize the network. In 2020, Eduardo da Silva raised concerns about smart agriculture's security, status, and future. Smart agriculture is a vulnerable target. Commercial, ideological, or terrorist objectives might justify attacks [14]. Terrorist groups, economic opportunists, and individual employees can create economic turmoil. Security is a critical resource in intelligent farming, helping to create reliable and efficient systems.

Several wearable devices have been identified in this research as a possible method for real-time monitoring of cow health, aiding veterinarians, and evaluating vital markers that can provide reliable information on the health of cows. Thus, WSN will lower the cost of cattle health care. A monitoring system that can capture rumination, heart rate, body temperature, bellowing, jaw movement, movement patterns when resting and walking, and disease prediction using an artificial neural network is required. Low energy consumption, fast speed, high performance, high precision, intelligence, and mobility are key. With all these research advances, real-world implementations of the new technologies are still lacking. There is no real-time health monitoring system with these features, especially disease prediction and secure cattle health monitoring [14, 15].

Physiological and behavioral data are mostly hand-collected by veterinarians. The device's durability is another concern with the above cattle health monitoring alternatives. If cattle are uncomfortable with equipment, they may remove sensors. Most approaches for predicting cow health use heart rate data. Wearable sensors for real-time cow health monitoring devices let veterinarians measure parameters and provide reliable information.

III. IOT BASED-LIVESTOCK INFRASTRUCTURE

In livestock, IoT networks monitor and track animal behavior. An IoT network supports the livestock infrastructure and gives access to its backbone. The IoT livestock monitoring platform can help cattle farming. IoT-powered livestock management systems give health information to cattle [16]. Using a collar or tag with sensors to monitor cattle position, temperature, and heart rate and wirelessly communicate the data to servers for processing and subsequently to farmers' devices. This system displays cow behavior via a Web Application. The system sends predicted result of disease classification with the sensor data to a user-friendly website. In this manner, farmers may treat sick animals early. The proposed cattle health monitoring system has four tiers i.e. physical layer, network layer, ANN, and web application.

A. PHYSICAL LAYER

This layer has two sensor nodes holding six body area sensors. Sensor nodes consist of a sensing unit, a processor unit, a transceiver unit, and a power unit as their core components. The sensing unit of the system comprises a sensor and an analog-to-digital converter (ADC). Sensor analog signals are converted to digital by the ADC and sent to the processor. The processing and transcribing unit consist of ESP 8266 12e Wi-Fi Module, the newest integrated chip built for a new linked world, and Raspberry Pi 3 Model B, perfect for Internet of Things (IoT) projects. The power unit is a LIPO battery of 3.7v 1000mAh. MQTT (Message Queuing Telemetry Transport) protocol is utilized to send data between ESP8266 12e and Raspberry Pi wirelessly.

1) STRUCTURE OF NODE

The designed sensor node attached to the collar with schematic is shown below:

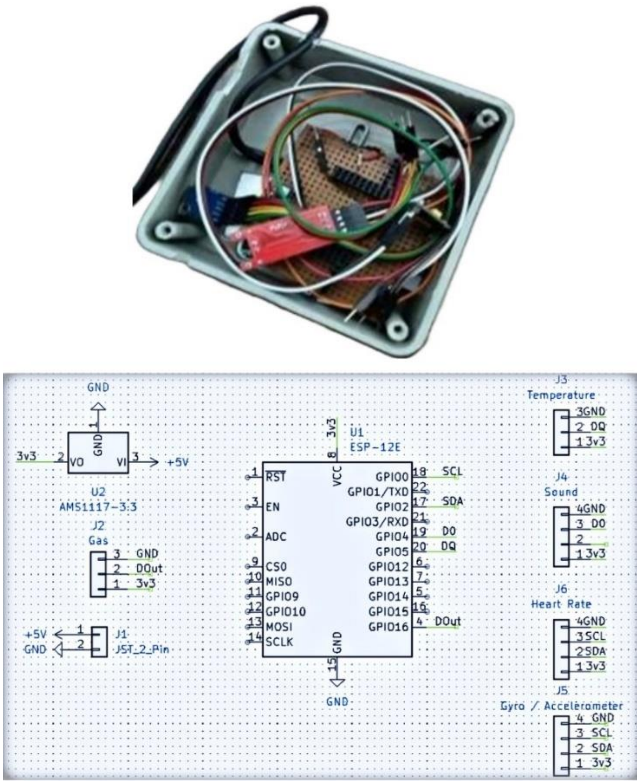


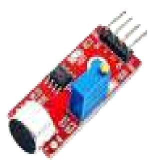
FIGURE 2: Cow collar sensor node

The sensor node deployed in the collar detects certain parameters using the hardware components shown in Table 1.The vital parameters being detected are:

1.1 TEMPERATURE MEASUREMENT

A Dallas Temperature sensor (DS18B20) with a built-in 12-bit ADC is employed [17]. The average animal temperature is 38.6°C. Temperatures can be taken from the cow's vagina, udder, ear, and rectum but the temperature is taken from a cow's neck.

TABLE 1. Components required to develop a sensor node.

Body Area Sensors	Model	Parameters Detected	Specifications
Temperature sensor **DS18B20** [17]		Body Temperature	• A power supply is 3.3V to 5V. • Accuracy is ±0.5°C. • It requires one digital pin for communication. • It is a waterproof sensor.
Pulse Oximeter **MAX30100** [18]		Pulse Detection	• Its operating voltages are 1.8V-5.5V. • Its Output type is digital. • Its interface type is I2C. • Heart Sensor weight is 1.2g.
Accelerometer **ADXL335** [19]		Grazing Motion	• Power Supply value is 1.8V- 3.6V. • It has Analog output. • Y axis has 0.5Hz – 1600Hz bandwidth. • Z-axis has a 0.5Hz to 550Hz bandwidth.
Gas Sensor **MQ138** [20]		Acetone	• Detection Gas: toluene, acetone, alcohol, hydrogen. • Working voltage: 5V DC. • The analogue output grows with increasing concentration, and the voltage increases as concentration increases.
Microphone **KY-037** [21]		Bellowing	• Input Voltage: 3.3V ~ 5V • It has two outputs: AO, DO. • There is a mounting screw hole 3mm. • It has four Pins i.e. AO, DO, G, +

The following sensors are connected to an ESP-8266 module with built-in Wi-Fi to transmit the attribute-value pairs to the base station wirelessly.

1.2 HEART RATE

MAX30100 is used to measure the heart rate [18]. Cattle have a 48-84 bpm pulse. Above this threshold, the pulse suggests stress or animal anxiety. The sensor counts heartbeats per minute. IR pair detects heartbeat from blood flow. To effectively monitor heartbeat rate, the IR transmitter and receiver must be aligned.

1.3 JAW MOVEMENT

ADXL335 senses cattle movement in the X, Y, and Z axes [17, 19]. An NED reference system was used to distort the body's axis from front to rear (X), horizontally (Y), and vertically (Z) before the investigation began, so that each of these three axes could be seen clearly. ADXL335 are low-power, 3-axis MEMS accelerometer modules with analogue voltage outputs that are radiometric. The sensitivity of analogue signal accelerometers is determined at a supply voltage and is given in millivolts per gramme. The ADXL335 sensor measures 3G in the X, Y, and Z axes.

1.4 ACETONE DETECTION

MQ138 gas sensor is used for the detection of acetone [20]. To detect any gas, the sensor must be located near the mouth of the calf, or if it is placed in the sensor box, it must have an opening, which is impractical because the sensor box must be waterproof to protect other electrical components. Intake of food(grazing and rumination) can also be used to detect ketosis.

1.5 BELLOWING

KY-037 sound sensor converts sound into electrical signals. As the movable plate (diaphragm) vibrates with the sound wave, the capacitance changes. Capacitance changes are turned into an electric signal [21]. A microphone turns sound into an electrical signal. The microphone's diaphragm vibrates additives. Add audible signal from vibrations.

B. NETWORK LAYER

The ESP 8266 Wi-Fi module installed in each sensor node sends sensor data to a web-based database. The ESP8266 links microcontrollers to a Wi-Fi network and enables TCP/IP communications [22]. Farmers and veterinarians may monitor animals from anywhere on the farm. The ESP 8266 Wi-Fi module transfers information for physical contact.

1) DESIGN OF A BASE STATION

The base station, or sink node, processes body area sensor data. It's a strong device. The base station is the gateway to the WSN. A credit-card-sized PC Raspberry Pi 4 Model B as a base station is utilized. Raspberry Pi may be used as a desk computer with a monitor, keyboard, and mouse. It can run Debian-based Linux, or Raspberry Pi OS [17]. An Ethernet cable or USB Wi-Fi adapter can connect the Raspberry Pi to a LAN for SSH access. MQTT is the most popular IoT protocol for data transfer between broker (base station) and client (ESP) [23].

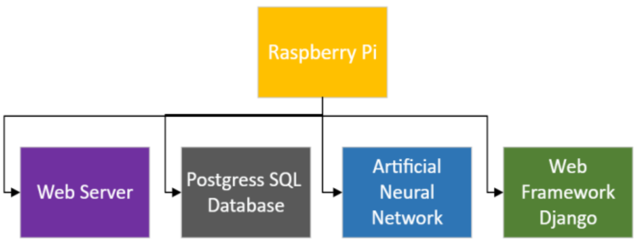


FIGURE 3: Functions of the Base Station.

2) WIRELESS COMMUNICATION

MQTT is a popular used in IoT and M2M applications due to its simplicity and open-source nature. MQTT is asynchronous, publish/subscribe protocol that works over TCP transport protocols with TLS and SSL for security, making it lightweight and straightforward to implement.

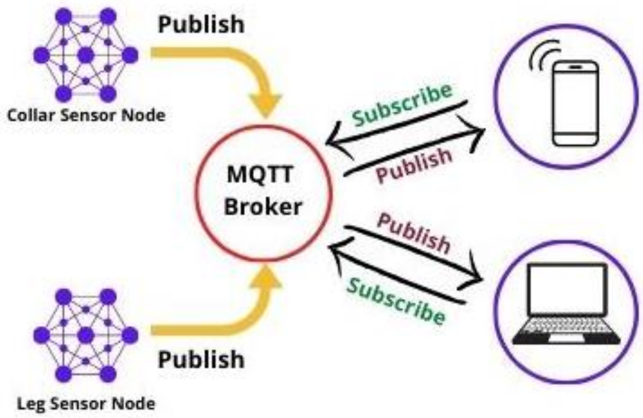


FIGURE 4. Working of MQTT protocol.

3) IMPLEMENTATION OF NETWORK SECURITY

Insider security and outsider security have been implemented for data efficiency and reliability in this system's general architecture [6]. The data transmission between the sensor nodes and base station is protected against insider access. For data transmission between the base station and the website that keeps data in the system's database, outsider security is introduced.

3.1 COLLECTION OF DATA THROUGH SECURE NODES

Insider Security covers secure sensor node connectivity/communication with the base station or Raspberry Pi. By adopting Mosquito’s inbuilt security plugin, the sensor nodes are authenticated with *sha512-pbkdf2* encrypted passwords [24]. It allows the communication between the node and base station to be secure using SSL/TLS. The diagram below shows the flow of insider security integrated into this system.

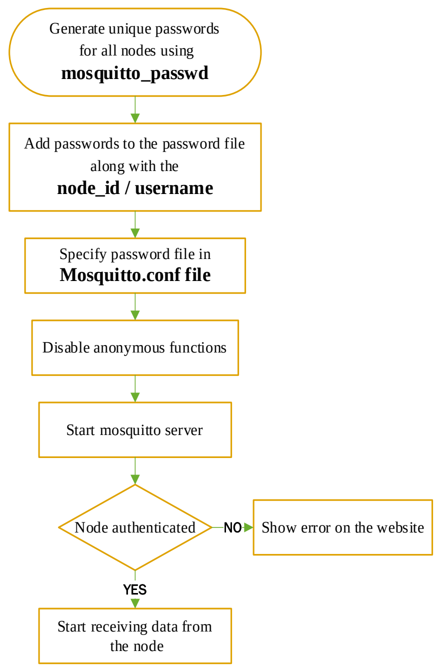


FIGURE 5. Insider security between sensor nodes and base station.

3.2 USER AUTHENTICATION

Outsider Security concerns the security of user-to-web application communication. It is implemented using Django-two-factor authentication. TOTP devices are generated per user to allow for multi-user 2FA [25]. TOTP allows for unique passwords generated through a standardized algorithm that uses time as an input. This allows the user to get their TOTP key even when they are offline.

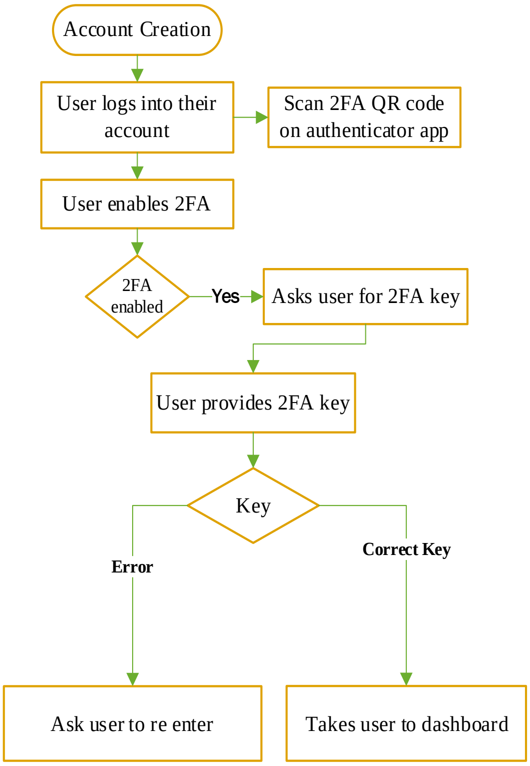


FIGURE 6. Outsider security between user and web application.

A. IMPLEMENTATION OF ARTIFICIAL NEURAL NETWORK

An artificial neural network (ANN) is one of the prediction approaches utilized in animal sciences because of its capabilities as an information processing system inspired by biological structure in the human brain [26].

This section discusses the processes of training, implementation, and testing of the model.

The real-time dataset for the implementation of ANN was gathered over a span of 7 months from different locations in Punjab, Pakistan as shown in Table 3 above. The data collected from cows under the supervision of a veterinary doctor was for specific diseases which are often found in the locals.

The balanced dataset as shown in Figure 7 below was preprocessed using the scikit library [27]. The data were cleansed by eliminating missing values, smoothing noisy data, resolving inconsistency, and reducing outliers by data preprocessing. Figure 7 below shows the number of instances for every output class was equal. Standardization of a dataset is a frequent prerequisite for several estimators based on machine learning: their performance will be compromised if features aren't normalized individually. For this purpose, the proposed model was trained with a dataset normalized using The Sklearn Standard Scaler removes the mean and scales to unit variance in order to standardize characteristics. Classifiers based on machine learning cannot directly interpret categorical values; thus, such data must be transformed to nominal values. The Neural model was trained on data with categorical values converted into nominal values using Scikit Learn Library [28]. One-Hot encoding and Label encoders both were used during the preprocessing phase. Label Encoder was used to convert each categorical value into a numeric value and then One-hot encoding was used to convert the data by splitting the output column into multiple columns depending on the initial value in the dataset.

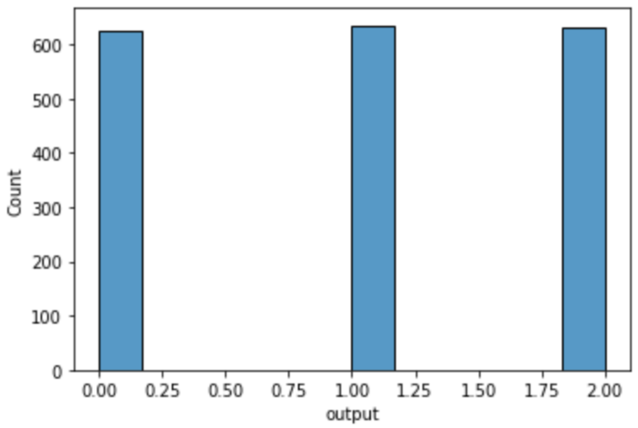


FIGURE 7. Balanced dataset for ANN.

Table 3. Summary of a collected dataset for ANN.

Diseases	Dataset	Month	Data Collection Location
Healthy cow	1300	November and January	UVAS (Pattoki) and Aspire Dairy Farm
High Fever	650	March	Padana Village
Ketosis	650	April	Hier Village

1) PREPARATION OF THE DATA SET

2) CORRELATION MATRIX

The correlation matrix is a Table that illustrates the correlation coefficients between the various variables. The line of 1.00s extending from the upper left to the lower right is the major diagonal, which demonstrates that each variable always corresponds precisely with itself. This matrix showed us that the **'z'** matrix had a minimal correlation with the output parameter and was dropped before training the model which improved the accuracy of the trained model.

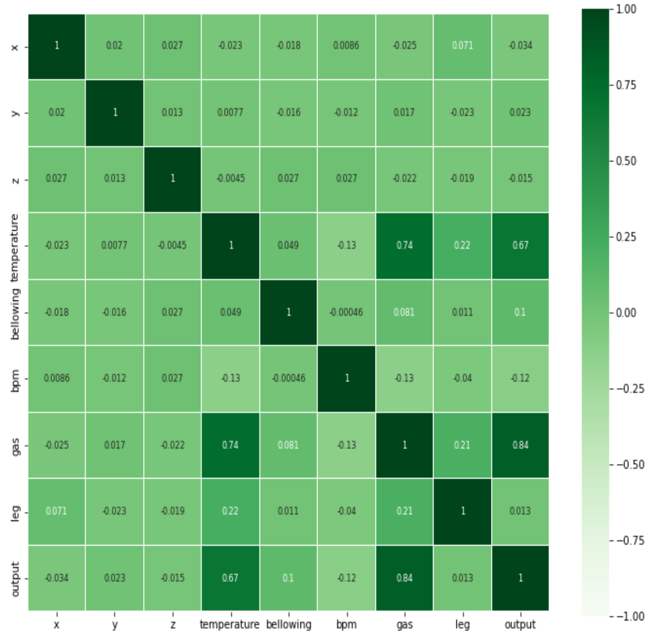


FIGURE 8. Correlation matrix of the dataset

3) WORKING OF ANN

Real, discrete, or vector-valued functions can be approximated using an ANN, which is resistant to errors in training data [29]. ANN learns the mapping between inputs and outputs from the training data in a way that is highly parallel and distributed process of automatically tuning the weights [30]. The model is intended to demonstrate the relationship between species-specific sensory data inputs and animal sickness without highlighting the process, initial and boundary conditions, and the nature of the associations. The network is trained using the backpropagation technique and optimized using the loss function and optimization algorithm defined during model compilation [31]. Although we have built the sequential ANN model using Keras deep learning API, the backpropagation algorithm's generic pseudo code is shown in the Figure 8 [31].

procedure TRAIN

$X \leftarrow$ Training Data Set of size mxn

$y \leftarrow$ Labels for records in X

$w \leftarrow$ The weights for respective layers

$l \leftarrow$ The number of layers in the neural network, 1...L

$D_{ij}^{(l)} \leftarrow$ The error for all l,i,j

$t_{ij}^{(l)} \leftarrow 0$. For all l,i,j

For $i = 1$ to m

$a^l \leftarrow feedforward(x^{(i)}, w)$

$d^l \leftarrow a(L) - y(i)$

$t_{ij}^{(l)} \leftarrow t_{ij}^{(l)} + a_j^{(l)} \cdot t_i^{l+1}$

if $j \neq 0$ **then**

$D_{ij}^{(l)} \leftarrow \frac{1}{m} t_{ij}^{(l)} + \lambda w_{ij}^{(l)}$

else

$D_{ij}^{(l)} \leftarrow \frac{1}{m} t_{ij}^{(l)}$

where $\frac{\partial}{\partial w_{ij}^{(l)}} J(w) = D_{ij}^{(l)}$

FIGURE 8. Pseudo code of Back-propagation Algorithm.

This system has been trained to do multi-class disease classification using a three-layer (input, hidden, output) MLP-based feedforward backpropagation ANN. The performance of this network using the ReLU and SoftMax activation functions was assessed. The number of layers was capped at three because adding too many hidden layers leads the network to memorise the training set and hinders its ability to generalise to new input sets (Breiman et al., 1984). After splitting (2/3 for Training and 1/3 for testing) the dataset into training, validation, and testing datasets, an MLP-based feedforward backpropagation network with a single hidden layer, 7 neurons per hidden layer, 7 input neurons, and 3 output neurons was created as shown in Figure 9.

The initialization procedure involved providing weights and biases to the layer. Following the completion of the initialization procedure, the created neural network must be trained Adaptive estimate of first-order and second-order moments was employed to update the weights of the neural network using the stochastic gradient descent approach called Adam optimization [32]. To learn something new, the learning algorithm must go through the training dataset a certain number of times, and this hyperparameter is expressed as epochs. The error between the target and computed output values is minimized iteratively until the termination condition is fulfilled, i.e. the total network error is reduced to a predefined level or a predefined number of training steps has been reached. The model was fit on the training set with a batch size of 10 and 100 epochs. The model after testing was saved and deployed on Raspberry Pi for processing real-time input data and displaying the results for the user on the Web Application.

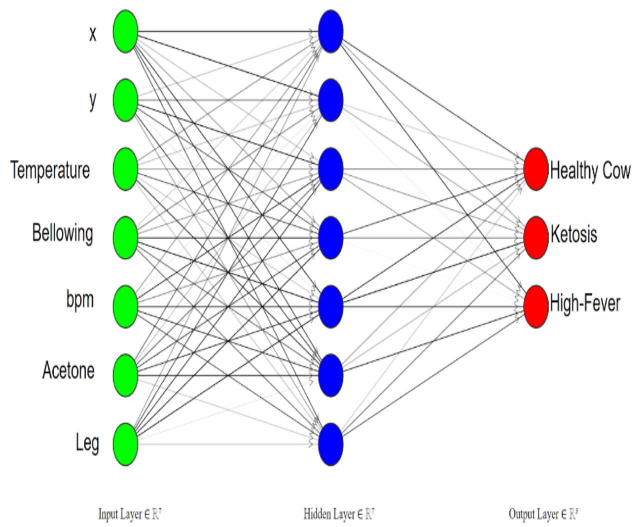


FIGURE 9. ANN architecture

4) PERFORMANCE MEASURE ANALYSIS

The suggested architecture is evaluated using the most standard performance measurement parameters, namely precision, recall, and the F1-measure. Due to the multiclass classification, the selection of these criteria was determined. [33]. The formulas to calculate these performance parameters are given in (1)-(4).

$$Precision = \frac{TP}{(TP + FP)} \tag{1}$$

$$Recall = \frac{TP}{(TP + FN)} \tag{2}$$

$$F1 - Score = \frac{2 \times (Precision \ \times Recall)}{(Precision + Recall)} \tag{3}$$

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \tag{4}$$

where TP, TN, FP, and FN stand for total positive, total negative, false positive, and false negative, respectively. Precision is defined as the exactness of measurements, and recall is the fraction of relevant (i.e., TP value) instances retrieved throughout an experiment [34]. Precision (or exactness) is the percentage of instances predicted as positives are positive (or are relevant. Recall (or completeness) is the percentage of positive instances predicted as positive. Notable is the fact that both precision and recall, relative measures of relevance, were determined to be 97.74 percent using eq. (1) and (2).

Accuracy represents the proportion of instances that were correctly classified, which was also approximately 98 percent using eq. (4). The F1 score , a simpler metric that incorporates both precision and recall, was also 97.7 percent calculated using the formula in equation (3). Using the Confusion matrix, the performance of the classification was visualized and the summary is displayed below in Figure 10:

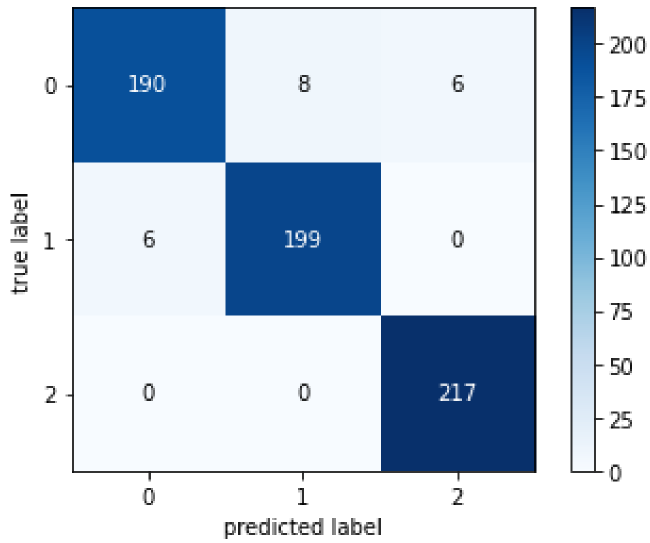


FIGURE 10. Confusion metrics of the trained ANN model.

Throughout the training of the model, the Figures 10 and Figure 11 below illustrate an increase in accuracy and a decrease in loss up until the stability

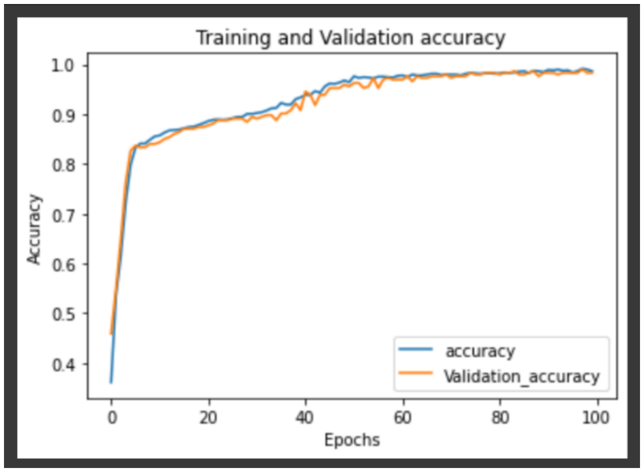


FIGURE 11. Training and validation accuracy

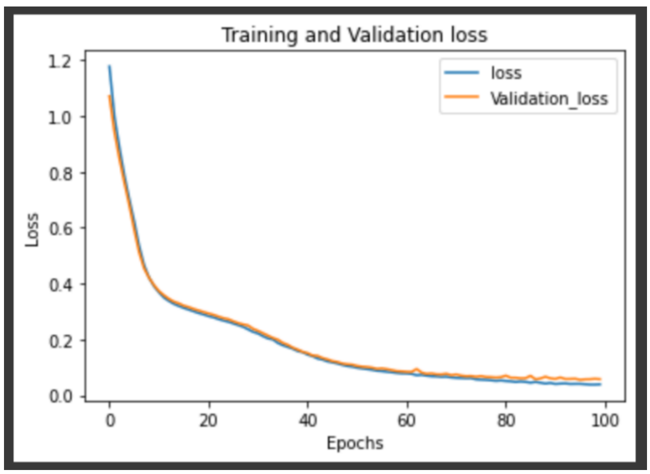


FIGURE 12. Training and validation loss.

B. APPLICATION LAYER

To manage and process the data coming from the nodes a Web application is developed using Django as a backend framework and SQLite as system's database to display not only sensor data but also processed data from the output nodes of the artificial neural network. The web application is user-friendly and responsive for all devices like mobile, tablets, and computer monitors. The responsiveness of the website is because of the use of media queries for different screen sizes.

Access to the web dashboard is available to authenticated users only. Among numerous security techniques, authentication is the first line of defense and the foundation for access control. For Authentication, users must first be validated prior to being granted access to application data. Authentication is the process of establishing that a person is who he or she claims to be [35] Authentication allows the recipient of a message to verify that it has not been altered or corrupted.

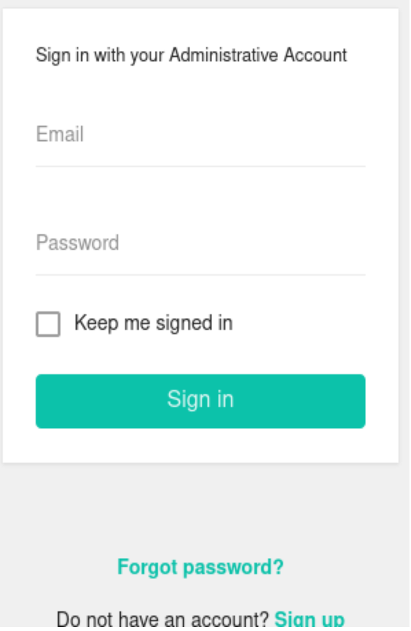


FIGURE 12. Sign-in Form.

The application layer consists of following tiers described below:

1) FEATURES

Web application presents product with appealing landing page, features, user guide, and contact us option. It offers login and registration for "cattle care" users. Once signed into "cattle care," the online app takes the user to the dashboard. In the dashboard portion, the online application shows cattle vital statistics extracted from the database by sensors and any suspected disease after being processed by an artificial neural network algorithm.

2) HOMEPAGE

The homepage has a simple navbar to navigate through the web app with signup and login buttons. It introduces the product to the visitor. It provides basic information about all the features of the product. "Cattle care" will provide information on how to use the product and any precautionary measures to take to avoid any damage. It will provide the option to contact the developer team if a user has any queries.

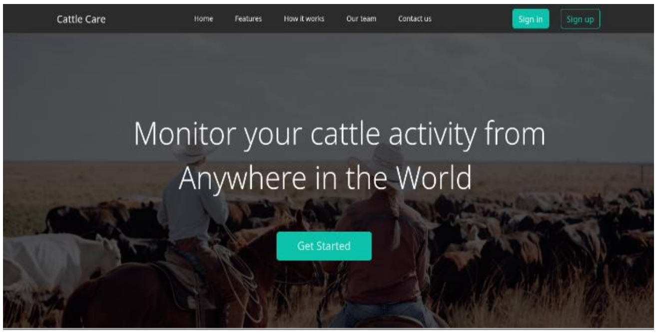


FIGURE 13. Homepage of web application.

3) DASHBOARD

The user dashboard interface has a side drawer for navigation. The main page shows the user's profile picture, username, and email. It provides total data of healthy and sick cattle and active or offline devices. All cattle tracked by this project are included in a table with their id, temperature, heart rate, and ketosis status. The user may click on any entry in the table to view that cow's health data and analysis.

4) DATABASE

SQLite is a C library that provides a fast, reliable SQL database engine [36]. This project uses SQLite, the most popular database engine. Using a valid id and password, the admin may access the database management system. The admin may add, remove, or change any product, gadget, or cow. Administrators may download any information. The admin may monitor new devices. The dashboard allowed for all of these functions.

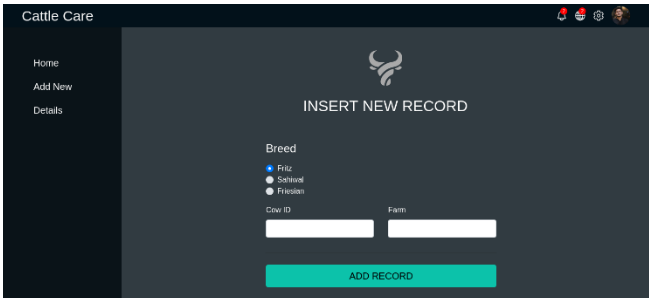


FIGURE 14. New entry record.

IV. RESEARCH ISSUES AND CHALLENGES

The final product can inform the user about individual cattle health status, but some uncertainties and challenges were encountered along the way. Due to worldwide chip shortage, difficulties were faced in the procurement of hardware such as Raspberry Pi.

The proposed system is based on real-time cattle health monitoring for which sensor data had to be acquired to train and deploy a high-performing ANN model which was difficult keeping in mind the accuracy required in health applications on unseen data. It had to be made sure that the dataset gathered is accurate and under the supervision of veterinary doctors at all times for cross verification. This was important as it was required for the final product to not just best fit the training data but predict unseen instances accurately. As the local farm animals are not used to the sensor-based collar, it was difficult to gather data from multiple animals as every individual took some time to get comfortable. Considering all the difficulties being faced to gather an accurate dataset from far away farms with access grants through a formal permission letter, the Neural model was only trained on the two of the most common diseases found locally. As the product is based on Machine Learning (ML), there is always a risk of the scope of error which may result in minor misclassifications as shown by the confusion matrix earlier.

V. FUTURE RESEARCH DIRECTIONS

The wireless sensor network is a unique technology that has changed communication ways and brings in a lot of money for energy, health, agriculture, etc. Future sensor node advancements must deliver powerful and cost-effective devices for animal health monitoring systems. As the sensor node's battery life is limited, using Li-Ion rechargeable batteries increases maintenance costs. Solar energy should be employed in this regard. Solar power is available throughout the day that can be used to guarantee a longer lifetime with autonomous operation as solutions must be energy-efficient. This system employed low-cost wearable body area sensors since the cost is a consideration for sensor nodes. ADXL335 accelerometer monitors cattle ruminating, standing, and walking, although adding sensors may be uncomfortable. Animals, primarily black and brown cattle, are tough to determine differently but cattle activity may be detected using a camera. Day and night images data may be gathered to train the learning model for 24 hours instead.

An artificial neural network is used to forecast illnesses (High-fever, Ketosis) after collecting datasets of healthy and sick cows' temperature, heart rate, lameness, and behavioral activities (grazing, standing, lying, etc.). ANN may be used to predict other diseases commonly found in livestock animals such as Mastitis after collecting larger datasets.

Authentication systems are utilized to safeguard this system due to the need of precise data. Otherwise, data-driven decisions would fail. Integrity, availability, and availability of data should be managed in livestock monitoring systems. Security of the system should be enhanced by integrating other cyber defense techniques such as Firewalls that may prevent harmful assaults. WSN's autonomy may make these options fail but better methods like HRM can be adopted to mitigate harmful attacks.

VI. CONCLUSION

This system is designed to support cattle farm owners by making the able to predict cattle diseases and monitor cattle health parameters from remote locations which will increase farm output with less labor costs. The proposed system is capable of informing the user of individual cattle health data coming from sensor nodes placed on different body areas through a secure wireless communication channel. The base station will be collecting data wirelessly from authenticated sensor nodes only and performing AI algorithms on that data after storing it in the system's database. The end-user will only be able to access information through system's web application after they have been authenticated by the health monitoring system. The user will be able to see predicted result from ANN model with performance measure evaluation of nearly 98%. The web application will be receiving signals from the base station in real-time that will be updated on the user interface as shown in Figure 15.

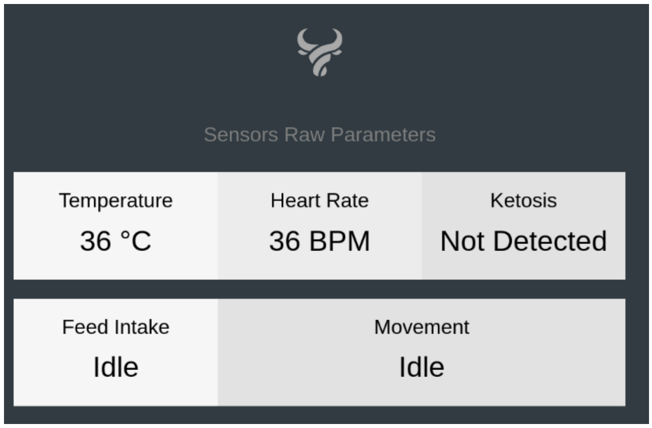


FIGURE 15. Recorded sensor data on web application

This information will prove to be highly valuable for the end-user to foresee possible health diseases that may be communicable which will allow them to take appropriate precautionary measures in a timely manner limiting huge losses. The health monitoring system will not only help the end-user to increase their production but bring the attention of others to this industry.

VII. REFERENCES

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