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A Pervasive Framework for Cattle Health and Movement Monitoring

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***Abstract*—The work proposed a veterinary healthcare monitoring and location tracking system for cattle. The health monitoring used the heart rate, body temperature, pulse rate and respiratory rate as vital signs which were monitored using ubiquitous sensors. The signals from these sensors were transmitted to an application in a server for processing. The application utilizes Artificial Neural Network for its decision. The system also utilizes a chip embedded in a cow that communicates with GPS to track the location of cattle at any given time. The system was implemented with Java Enterprise Edition 8. Experimental results indicated that the system did well in monitoring the health statues of the cattle. The results compared well with similar works and have the advantage over such works in the area of tracking the location of the cattle.**

Keywords— Pervasive Model, Veterinarian, Nutritionist. Wireless Sensor Network, Wearable devices, abnormality alert, Normalisation, Rustling

1 Introduction

Pervasive computing model also called ubiquitous computing is the concept that incorporates computation in our working and living environment in such a way that the interaction between human and computational devices such as mobile devices or computers becomes extremely natural and the user can get multiple types of data in a totally transparent manner [1]. This work proposes a vital signs health monitoring, detection and reporting system that uses wireless sensor network (WSN) and an intelligent system (Artificial Neural Network Algorithms). This proposed system is designed to monitor and report anomalies in health conditions of cattle by continuously processing their vital signs acquired by the sensors. To be sure of accuracy in the work, the following animal vital signs are measured by the sensors in order to make informed decisions on the state of the cattle. The vital signs include, heart rates, body temperature, pulse rate and respiratory rate. The work also tracks cattle using embedded chips which is useful against cattle rustling as it is prevalence in Northern Nigeria.

II Literature Review

In this section we reviewed related literature as well as surveyed different tools and techniques used in veterinary pervasive healthcare delivery.

Different types of systems used for cattle health monitoring were reviewed by [2] Their review focused on such health parameters like counting of steps, temperature, ruminating and body humidity of the cattle. The system reviewed by their work include systems using Electrocardiographic pills for cattle heart rate monitoring, system implemented with LabVIEW and Arduio and systems implemented using wireless Sensor Network and System development using IOT concept. They concluded that IOT based cattle health monitoring systems are more prominent.

A biosensor-based cattle health monitoring system that collected bio-signals of farm animals in an effective way was presented by [3]. The bio-signals of cattle measured included heart beat, breath rate and momentum. A zigbee module was used in transmitting the data based on wireless sensor Network (WSN). The bio-sensor zigbee modules were implemented as an integrated device on a single board for easy installation on the cattle's trunk.

The use of Arduino UNO microcontroller to monitor the various animal was presented by [4]. Parameters monitored included body temperature, respiration, humidity, heart beat and rumination. Their system also made use of ESP8266 Wifi module as transceiver. Also i-chart app was used to display the graph which was used in observing the body issues associated with the cattle. This enabled early detection of the disease which the cattle were suffering from.

A prototype wireless body temperature monitoring system that made use of wearable technology that provided continuous animal health data was utilised by [5]. Their prototype contained a sensor mote that contained temperature sensor for core body temperature measurement a head motion sensor for detection of angle of movement of cattle head and a GPS for detection of the exact location of the cattle. Other modules in their system included a heart rate sensor and a surrounding environmental condition monitoring module.

The installation of wireless sensors in farms to gather ecological parameters which facilitate monitoring of animals through Web from outside the farm as well as control of farm environment in remote locations was proposed by [6]. They submitted that environmental changes can affect cow performance through stress and disease in the farm.

The various sensors used in wireless network to monitor cattle health with the view of preventing harmful diseases that could cause several effects in farms were described in [7]. The sensors considered in their study included temperature sensor, humidity sensor and heart rate sensor. They further reviewed monitoring systems with the implication of each system.

An expert system of bio-information, which is combined with the smart devices using wireless sensor network (WSN) was described in [8]. The physiological signals were acquired by some wireless bio-sensor module. The smart device transmitted the bio-information by wireless network, which provided the real-time expert consultation function requirements for the purpose of bio-information analysis, storage and decision.

The presentation of the wireless sensor networks (WSN) to observe the human physiological signals by ZigBee technology was done by [9]. They developed a suite of home care sensor network system by ZigBee's characteristics.

A novel system that used radiofrequency identification (RFID) to non-invasively study a mouse's vital signs was proposed in [10]. The system comprised of a base post and a transponder. The transponder was rooted in a mouse and transmitted wirelessly with the base post. The transponder was motorized by the low frequency electric field transmitted from the base post and involved no internal power supply of its own. Code was written in C for the transponder and base station microcontrollers and a Matlab graphical user interface was also written for communication from the base station to a PC. Wireless data was transmitted with a Manchester encoding scheme, for which a novel method of software clock recovery was used.

The workability of wireless technologies used to create a platform for cattle health and behavior monitoring, which used both internal and external body sensors for monitoring cattle, was reported in [11]. The sensors communicated wirelessly with each other and were continuously connected over the mobile telephone network to provide a real-time view of data using standard web services.

The introduction of Condition Base Monitoring system (CBM) which focused on the challenges that related specifically to the backhaul of data from cattle mounted sensory devices including information protocols, power consumption, movement, activity range, information transmission volumes and herd size was done by [12]. The CBM technology has been based on a collar mounted wireless and sensor platform. CBM detected aspects of the physiology or behavior of an animal and reported abnormal conditions at an early stage which allowed the veterinarian to take appropriate action.

The presentation of a network of wireless nodes using ZigBee as a wireless communication protocol based on IEEE 802.15.4 technology standard for wireless personal area networks (WPAN) which monitored the vital signs of both sheep and goats was done by [13]. This smart system had the ability to detect the collective stress caused by the attack of any predator during the night. This system was capable of measuring the episodes of collective stress in the animal flock by using the variations of heart rates and corporal temperature of the animals. Therefore, the system can be considered as a tool to prevent the loss of the cattle, increasing production and profits from livestock facilities.

A wireless sensor network for wildlife monitoring was designed by [14]. In this system, specially designed collars with sensor node attached were put on wild animals. These collars acquired information about the desired parameters from the vicinity of the animal and transmitted it to the base station. The system was used to monitor the habitat, movement pattern and behavior of animals.

III Methodology

Rapid application development (RAD) is adopted as the methodology for this study because of its highly interactive systems development approach. (RAD) is an object-oriented method to systems development that includes a technique of development as well as software tools. The four stages of RAD which include planning, user design, construction and cutover [15]. The work provided a cloud based smart and intelligent system to detect cattle health anomalies as well as location tracking to guard against cattle rustling. Cattle health monitoring was done by the body sensors attached to the animal, which take the animal's vital signs and identification parameters then transmit same to the application in the cloud for processing. After processing the application is designed to inform the veterinarian and the nutritionist of the cattle health status. The second component of the work tracks the location of the animal using an embedded chip that communicates with the GPS. A comparison is carried out between the location of the farm and the current location of the animal and if there they are not the same an alert is sent to farm owner as well as the Livestock Guard for necessary action. Fig 1 shows the architecture of the proposed system.

Fig 1: Architecture of the Proposed work.

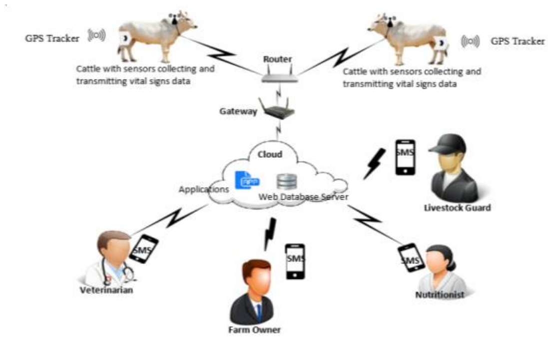
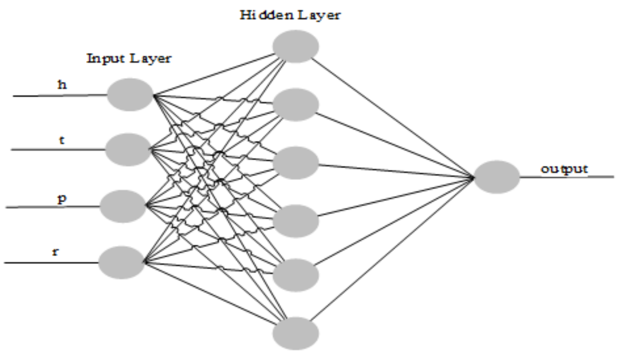


Fig 1 is made up of the cloud which houses the Dababase server and the Application. The section of the application that carries out cattle health monitoring uses a three-layer perception model. The three-layer perception model is as shown in fig 2. In fig2 the input layer has four(4) neurons which are fed up with four observations h_1, h_2, . h_{n-1}, h_n, t_1, t_2 . t_{n-1}, t_n, p_1, p_2 . p_{n-1}, p_n, and r_1, r_2, . r_{n-1}, r_n. representing the heart rate, body temperature, pulse rate and respiratory rate respectively.

Fig 2: A three-layer Neural Network Model



In fig 2 one hidden layer with six neurons was chosem. This was to optimize the ANN performance. The last layer in fig 2 is the output layer which consisted of the target of the detection model, which can be a normal or an abnormality in the health condition of the animal.

The sigmoid function was used as the transfer function. The database was divided into three sections, training data set, validation set and testing set. The mean square error (MSE) was choosen as the statistical standards for measuring the network performance. suppose that $\hat{X}_i$ be the vector representing values of n number of predictions. Also, X_i be a vector representing n number of true values. Then, the formula for mean squared error is given as:

$$MSE = \frac{1}{n}\sum_{i=1}^{n} \left(\hat{X}_i - X_i\right)^2 \quad (1)$$

Data Pre-processing

Input data collected using pervasive devices was converted from raw data into data representations suitable for the application through a sequence of operations. In the work min-max normalization for scaling down the data. The Min-Max Normalization was defined by [16] in equation (2):

$$\text{scaledX} = \frac{(X_i - \text{minX})}{(\text{maxX} - \text{minX})} \quad (2)$$

Database Design

When data is collected from the sensors on the body of the animal, which are the end devices sends the analyzed and processed data to the database in the cloud. The Entity Relationship Diagram (ERD) of the database is as shown in fig 3. The ERD has five tables namely Farm, Animal, Contacts, Message and

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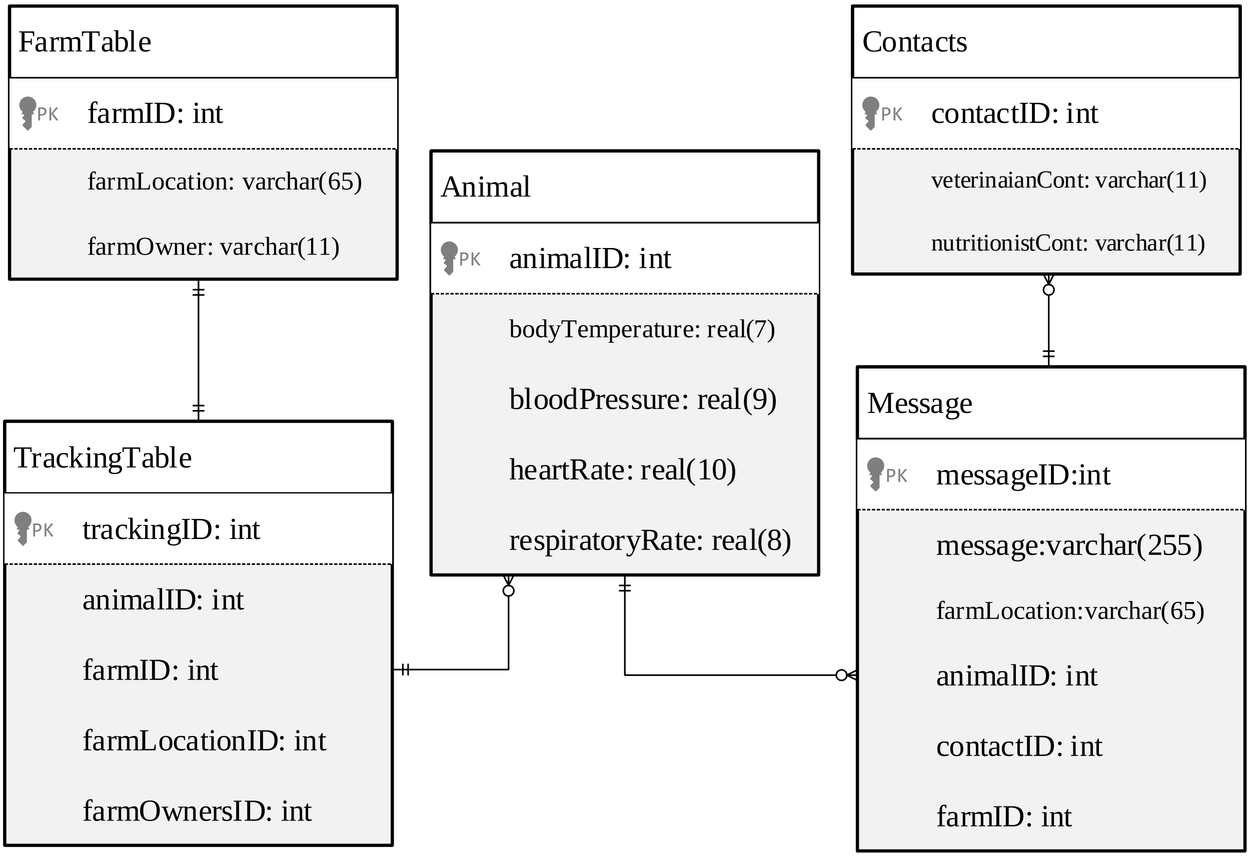
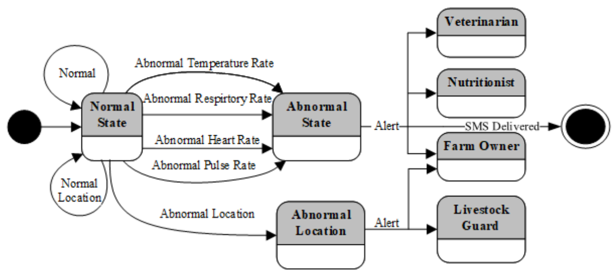
Fig 3: The ERD of the database of the Proposed System.



The State Diagram for the work is as shown in fig 4. Fig 4 indicates the various states the system can enter. Initially the system is in Normal state. This implies that the read vita signs are normal and the cattle are also in the owner's farm location. If any of the vita signs changes from its normal condition the system enters the Abnormal state. In the Abnormal state an alert is sent to both the nutritionist and the veterinarian. Similarly, the system continuously run checking the location of the farm against the location of the cattle. If the locations are different the system enters the Abnormal Location state. In this state an alert is sent to the Farm Owner as well as the Livestock Guard informing them that rustling has taken place.

Fig 4: The State Diagram of the work.



IV Simulation Results and Discussions

A total data size of 300 observations was used, out of which 207 where gotten from [17] and 93 observations were randomly generated using Microsoft Excel Formula to have semblance to the vital signs.150 observations detected as normal vital signs and 150 observations detected as abnormal were used for training and testing the model. The data for the cattle movement tracking was randomly generated but had semblance with spatial data. Java Enterprise Edition 8pr was used for the simulation. Ten experiments were carried out. Out of the ten experiments six were devoted to cattle health monitoring while the remaining four were devoted to tracking cattle movement.

Experiments on Cattle Health Monitoring

The input values to the experiments were as shown in column 1-5 of table 1. The input values are temperature rate, heart rate, respiratory rate and pulse rate respectively. The inputs were generated using MS Excel. The output of the simulation is shown in the sixth column of table 1. An output of 1 or approximately means abnormality. Once an abnormality is detected in the health status is detected, an alert is sent to both the nutritionist and the veterinarian. Table 1 indicated that animals identified with CattleIDs 1, 2 and 5 have abnormal health statues, while animals with CattleIDs 3, 4 and 6 are normal.

Table 1: Normalized Input Values and their Corresponding Results for Cattle Health Monitoring

CattleID	Physiological Signals Dataset				Results
	Temperature	Respiratory rate	Heart rate	Pulse rate	Anomaly/Target
1	-1.10204	0.068966	0.806723	0.492537	1
2	-3.14286	0.310345	0.537815	0.253731	1
3	-1.10204	0.54023	0.655462	0.358209	0
4	2.77551	0.827586	0.714286	0.410448	0
5	-2.32653	0.08046	0.87395	0.552239	1
6	0.938776	0.494253	0.537815	0.253731	0

Experiments on Cattle Monitoring against Rustling

Input into these experiments were CattleID, P, a central point represented in coordinates in terms of latitude and longitude, R (in metre) representing the radius of the farm. These values were initialized for each farm. Two pairs of random numbers were generated representing the coordinates of the current location, L, of the animal. The distance of the current location from the central point is compared against the radius of the farm and if found to be greater than the radius it means the animal is outside the farm. Four experiments were carried out. The inputs in the experiments as well as the output were as shown in table 2. Since we one farm was used the, R and P remain constant. An output of 1 indicated that the animal is out of the farm location. An output 0 indicated the animal is within the farm location. Once 1 was the output an alert was triggered and a message sent to the farm owner and livestock guard that the animal is out of the farm location. In table 2 animals with cattleID 80 and 79 were out of the farm location

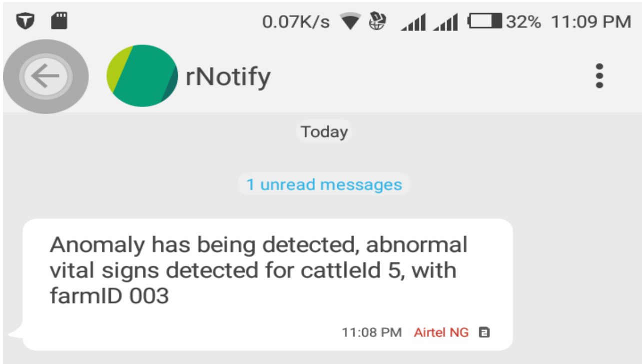
Table 2: Input Values and their Corresponding Results for Cattle Location Monitoring

CattkeID	farmID	R	P	L	Results
50	001	60	(7.4357N, 8.3222E)	(7.9942N, 9.9322E)	0
80	001	60	(7.4357N, 8.3222E)	(9.8088N, 9.9862E)	1
66	001	60	(7.4357N, 8.3222E)	(8.0932N, 9.912E)	0
79	001	60	(7.4357N, 8.3222E)	8.3137N, 9.8758E)	1

Notifications

The alerting system implemented in this work is the SMS alert. Two categories of alerts were sent. The first category is the alert on abnormality on the health status of the animal. This alert was sent to the veterinarian and the nutritionist. The second category is on the change in location of the cattle beyond the limits of the farm. This was sent to the farm owner and livestock guard. Telephone contacts of the above-named category of people were registered with the framework. A sample notification is shown in fig 5. In fig 5 health anomaly was detected on the vital signs of the animal identified with cattleId 5 in the farm identified with farmID 003.

Figure 5: SMS Alert for Vital Signs Abnormality Detection.



V Conclusion

In the work a framework for monitoring cattle health using vital signs as well as monitoring the location of the cattle to mitigate cattle rustling was proposed. The framework utilized pervasive wireless network sensors for monitoring the health status of the animals. A three-layer ANN was used in the decision making. The second sub model of the framework tracked the location of the animal at any point in time. The framework sent out notification once deviations were noticed either in the health status or the location of the animal. Results from the work compared favorably with the existing works but the advantage of the over other similar works was in detecting the location of the animals. The work is recommended for use in ranches and farms in Northern Nigeria where rustling of cattle is assuming a dangerous dimension

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