Development of IoT Based Smart Animal Health Monitoring System using Raspberry Pi

Seema Kumari[a], Dr. Sumit Kumar Yadav[b]

[a]Student, Department of Electronics, IGDTUW, Delhi-110006, India

[b]Assistant Professor, Department of Computer Science, IGDTUW, Delhi-110006, India

Abstract:

A prototype of smart animal health monitoring system based on IoT for real time monitoring of the physiological parameters such as body temperature, heart rate and rumination with surrounding temperature and humidity has been developed. Various sensors mounted on the body of animals gives the information related to their health status and user can be easily access those data using the internet. We have used raspberry pi3 as core controller which has inbuilt Wi-Fi, it processes the data sensed by various sensor and displays on the monitor and forwards to the cloud. User can access the information from anywhere using internet and an android app.

Keywords: IoT, Animal health, Raspberry Pi, Wi-Fi

1. Introductıon

"Animal Healthcare ensures that farmed animals are healthy, diesease free and well looked after. It also aims at preventing or managing – outbreaks of serious animal diseases, and in doing so support the farmers, protect the welfare of farmed animals and safeguard public health from animal borne disease".

In India 54% of population is directly dependent on agriculture and most of them practice mixed agriculture. Animals such as cow, buffalo, goat and sheep contribute significant role in mixed agriculture for their livelihood specially in case of crop failure. But these animals also suffer from many diseases[23]-[25],[36] and sometimes the disease is dignosted too late to save the animal, so diseases act as a negative influence on the livestock production system, thus setting off a cascading "affect of low production, low income, and subsistent livelihood"[39]. The implications of cattle diseases in livestock can be complex and generally "go well beyond the immediate effects on affected" farmers or owners. These diseases have numerous affects, which include losses in production for the farmers (production losses, cost of treatment, market disturbances), loss of income from activities using animal resources (energy, transportation, tourism). Moreover 60% of the human diseases are zoonotic in nature i.e infection is spread from animals to human being. Zoonotic diseases include Tuberculosis, Glanders, Anthrax, Rabies, Avian and Influenza. These diseases are quite harmful so there is need to control the spread of zoonotic diseases. Highly contagious livestock diseases such as 'foot and mouth disease (FMD)', 'hemorrhagic septicemia (HS)', 'mastitis, peste des petits ruminant (PPR)' and "surra in cloven footed domestic animals" cause irreparable economic losses to the farming community[35]. The total economic loss [31] due to disease in cattles can be summarised as the "sum of mortality loss [34], loss in milk yield and cost of treatment of affected animals". In India overall Morality loss in cattles is approximately 15%, which is quite high [22].

These reasons show the requirement of a system for real time monitoring of the animal health and for controlling and preventing the outbursts of diseases at larger scale. Technology is already a part of modern farming and is playing an important role with the advancement in available systems and tools. Livestock farming has been one of the biggest areas of development in electronic in recent years.A lot of scholars are focused on the development of animal health monitoring system.

This paper is divided into six subsections. **Section 2** describes previous work carried out in area of animal healthcare monitoring system, important surveys and studies carried out to figure out animal diseases and their impact on economy of nation. **Section 3** discusses our proposed solution based on literature review conducted. **Section 4** discusses the requirements of resources for the prototype of Iot based Smart Animal Health Monitoring System. **Section 5** discusses the implementation, testing and result of the project. **Section 6** concludes & discusses our future research work.

2. Literature Review

Anuj et al. [2] have designed and developed a prototype of Animal Health Monitoring System (AHMS) for monitoring the physiological parameters of the livestock. Here, IEEE 802.15.4 & 1451.2 standard based – sensor module is being developed and implemented with the help of Zigbee device and PIC18F4550 microcontroller. The graphical user interface (GUI) is implemented in Lab VIEW 9.0 as per IEEE1451.1 standard. The prototype model has been developed and tested with better accuracy.

Anushka et al. [3] have proposed Smart health monitoring system for animals using Zigbee Sensor modules. In this system various sensor modules have been used for continous monitoring of rumination, body temperature, heart rate and environmental temperature.

Wietrzyk and Radenkovic et al. [7]-[9],[28] defined the animal health surveillance system based on ad hoc wireless sensor network determined that the livestock farmers can take preventive measures at the initial stage to reduce the propagation of diseases with the help of measured data. Chao et al. [10**]** presented and developed an Animal monitoring algorithm for providing better environment and healthcare to strays as well as to enhance their adoption rate. They used Arduino to build Wireless Sensor Network, RFID (Radio Frequency Identification) to distinguish strays and IoT (Internet of Things) for connectivity to internet.

Nadimi et al. [11]-[13] presented a 2.4-GHz ZigBee-based mobile ad hoc wireless sensor network (MANET) for the classification and surveillance of livestock behaviour. They demonstrated some advantages such as energy efficiency, better communication reliability, least rate of pocket loss. Hopster et al. [16] have presented two techniques for monitoring stress in cattle. They have used “polar spot tester (PST)” and “lectrocardiograph (ECG)” to propose the system and also provided the output of their study. They have realized that “PST” is an appropriate methodology for the heart beat measurement of cattle and assessed that the apposite factor for the animal behavioural study is heart rate.

Hugo et al. [17] designed a system to identify animals in the livestock with following specifications like low cost, energy efficient, and robustness. Jacky et al. [18] developed a “Mobile Monitoring System based on RFID” to handle the cattle efficiently with the help of “dynamic information retrieval, location identification and behavior analysis over a wireless network”.Ji-De et al [19] presented the technique with an embedded system utilising “IoT sensors”. The system consists of smart infrastructure which measures different parameters and communicate among themselves. Huircan et al. [20] presented cattle monitoring in cropping fields based on a zigbee and utilised the scheme of localization in WSN**.** Lovett et al. [21] presented a measurement technique using “infrared thermography” for detecting “foot-and-mouth disease” of livestock. Their study was foccussed at estimating infrared thermography as a screening technique for FMDV-infected animals and its attainable usage in the identification of suspected cattle for sampling and confirmatory diagnostic testing during FMD outbreaks.

Janzekovic et al. [27] presented a polar sport tester (PST) based heart rate monitoring technique for cattle. The parameters which are used for detection of disease for different animals are body temperature and heartbeat rate. Ariff et al. [29]-[30] proposed and developed “Livestock information system (LIS) on Android Smartphone” for real time monitoring of state of health of animals. In the developed device, Smart mobiles use bluetooth technology for communicating and processing the data of sensors. It also demonstrates the physiological parameter like heartbeat and temperature of the animals in real time.

The real-world application of the presented system has not been done yet in despite of all these improvements in research. At present we do not find any animal health monitoring device in Indian market which can monitor on the go. Physical factors of animals are being examined by veterinary doctors most of the times manually. At present livestock farmer’s encounters so many difficulties on monitoring the animal health so there is an imperative need of transformation of theoretical information to practical systems. At present systems to measure health parameter of animals mainly concentrate on measuring heartbeats to predict status of fitness of cattle.The survey of literature discloses that the vital technique to gather precise data of animal health can be a set up of hardware and software which can be mounted on the body of animal and can be remotely accessed. The set up can be very efficacious for veterinary doctors to prescribe proper medication at right time which can reduce the cost of treatment. Moreover the livestock health care would become affordable and cheap for farmers.

3. Proposed Solution

In this paper we have proposed an “IoT based smart Animal Health Monitoring System”. In this system critical parameters affecting cattle health like body temperature, heart beat and rumination are continuously monitored. The core controller can process the sensed values of sensors. The raspberry PI 3 model can be used as a core controller which is Wi-Fi inbuilt and database can be created on cloud using IoT so sensed data can be found on internet from anywhere.

Farmer or dairy owner can access the information using an android app in mobile. An email can also be sent to farmer so that farmer can get the data easily and can monitor the health of his cattle. This regular monitoring of animals health will help the farmers and dairy owners to know about the disease at its initial stage only and hence animal can be given proper treatment and in this way it will help to reduce the mortality loss and other economic losses. Thus this system can be quite helpful and crucial for the welfare of farmers who practice mixed agriculture.

Data of database at cloud can be shared **to "Department of Animal Husbandry, Dairing & Fisheries, Ministry of Agriculture & Farmer's Welfare, Govt. of India** and different **educational institutions** and **vetenary hospitals"**. These data can help the government in making animal healthcare policies and can help the government in better targetting to specifically affected areas. It will also help in reaserch and devlopement in vetenary science.

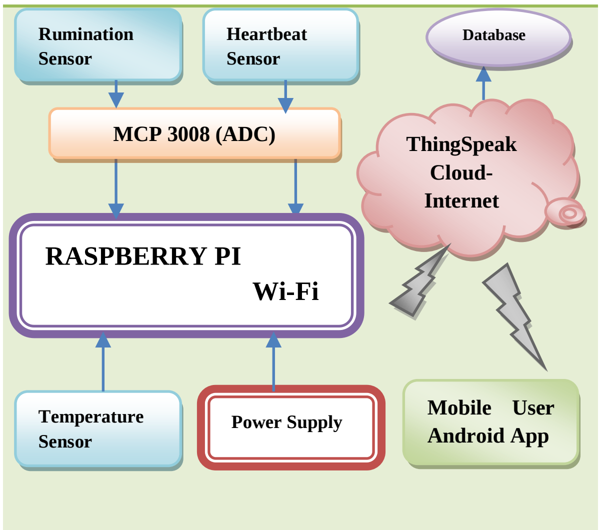

Fig. 1:Block diagram of animal health monitoring system.

4. Resources Requred

4.1 Hardware Used:

The hardware is composed of the Sensor module, Analog to digital converter (ADC) and Raspberry Pi module.

4.1.1 Sensor module

Sensors have many functions, like detection, collection, calculation and routing of surrounding data. These are used for real-time monitoring of various health parameters. Such type of sensors will be mounted on the cattle's body, which will continuously monitor the health parameters of the cattle like heartbeat rate, body temperature and rumination and sends output in the type of electrical signs. These signs are then compared to a standard limit of normal values. The Sensors like "body temperature sensor, heart beat sensor and rumination sensor" are used in the IoT based smart animal health monitoring system. These sensors are connected to the ADC (analog to digital converter) and raspberry pi. So sensor module will be mounted at the body of cattle so that critical parameters affecting cattle health like body temperature, heart beat and rumination will be continuously monitored with the help of different sensors discussed below.

4.1.1.1 DS18B20 Body Temperature Sensor Cable

DS18B20 sensor is utilised to measure the body temperature of the cattle. There are a numbers of infections which can occur in cattle when the core temperature of the animals changes. So it is necessary to monitor body temperature. The usual cattle temperature is **38.5^0C-39.50^0C**.The diseases related with body temperature lower than normal are milk fever, poisoning, indigestion etc. and when the temperature is more than 41ºC, diseases occurs are anthrax, influenza and foot and mouth disease.

DS18B20 has unique 1-wire interface which enables it to communicate with devices easily. It can measure temperatures from -55°C to +125°C (-67ºF to +257ºF).

4.1.1.2 Heartbeat Sensor

The rate of heart beats per minute (BPM) is the critical factor in evaluation of health. Normally in a fit cow the heart beats in the range of 48 to 84 times in a minute. Multiple diseases and uneasiness causes fluctuation in BPM. "Heartbeat Sensor is a well-designed plug-and-play heart-rate sensor"[15]. It is an analog sensor but raspberry pi does not support analog sensors so an "analog to digital converter (ADC: MCP3008)" is used. The sensor is interfaced with ADC then to Raspberry Pi.

4.1.1.3 Rumination Sensor Module

Rumination is directly linked to the health status of animals. They stop ruminating normally as soon as they start feeling uneasy due to physical problem or some disease. So it indicates that animal is normal and health. Its also a part of the digestion in animals**.** Normally an animal ruminates almost "one third of a day (9-10 hours). The variation in rumination signifies the disease like food digestion, mastitis, metabolic calving disease etc. Moreover the coming back to normal rumination is fantastic signal of successfulness of treatment. The monitoring of rumination of the cattle is required because it can give quite precise status of the health of animals [14].

We have used Accelerometer ADXL335 for developing "rumination sensor"[4]. "ADXL335 is a energy efficient, small, and inexpensive, affordable device which can be used to measures the 3-axis acceleration with a range of ±3g. The ADXL335 output signals are analog voltage that is proportional to the acceleration. The advantages, drawbacks, and specification are discussed in" [5]. It can also work in the static and dynamic measurement of the acceleration. "By measuring the amount of acceleration due to gravity, an accelerometer can figure out the angle it is tilted at with respect to the earth"[32]. The accelerometer can figure out the speed and direction of movement of animal jaw by detecting the "amount of dynamic acceleration" and thus by observing the sensed data we can get to know whether its normal or not . The accelerometer is very easy to interface with MCP3008 ADC using 3 analog input pins, and MCP3008 is connected to Raspberry Pi3 which gives the digital value of analog output of ADC.

"The operating voltage range of the ADXL335 module is 1.8V-3.6V and it is operated at a fixed voltage of 3.3V. At the 3.3V, the maximum output voltage of the accelerometer are - 560mV for the X-axis, +560V for the Y-axis, and +960mV for the Z-axis".

4.1.2 Raspberry Pi Module:

"The Raspberry Pi is a low cost,credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python"[37].

Fig. 2: Raspberry pi (top view) [38]

4.2 Software used:

The practical realisatio of hardware usage for all necessities are supported with the capability of the supporting software. The main theme of 'IoT' is being employed in the enforcement of this solution, makes the need for software a primary attribute.

i.) A common programming platform has been used to build for interfacing of the discussed hardware with one another and web server, and for accessing of data by the end user. The Raspberry Pi module, ADC and the sensors communicate by means of the python script run on the Raspberry Pi.

ii.) ThingSpeak Cloud:

The ThingSpeak API (Application Programming Interface) is "an open source Internet of Things (IoT) [1],[26],[33] which collects incoming data, timestamps it, and give outputs to it for both human users (through visual graphs) and machines (through easily parse-able code)". It acts as a data base to store all the data related to animal health and displays the information received from the Rpi in graphical form. Moreover, ThingSpeak enables us to create "applications around data collected" by different sensors. It provides " real-time data collection, data processing, and also simple visualizations for its users. Data is stored in channels, which provides the user with a list of features".

iii) Mobile User/Android Module:

This module is installed as an Android app in the users phones and display the health status by connecting to theThingSpeak Cloud.

5. Hardware Implementation

5.1 Interfacing Diagram

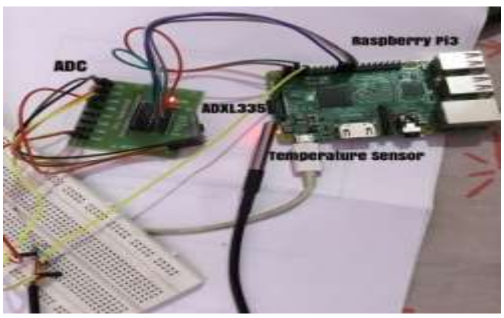

Fig. 3: Interfacing diagram of Temperature sensor and ADC with RPi.

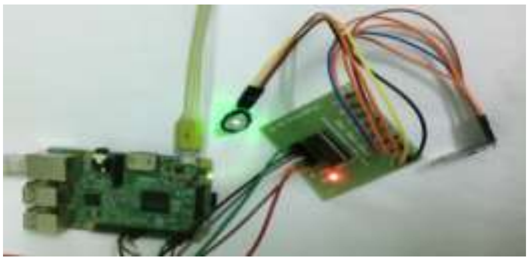

Fig. 4: Interfacing diagram of Heartbeat Sensor and ADXL335 with ADC and RPi.

5.2 Procedure Followed

The health parameters of animals are measured by sensors (Temperature Sensor, Heartbeat Sensor and Rumination Sensor) interfaced with MCP3008 and Raspberry Pi.

a) After measuring data, i.e. in the normal range/ out of normal range, the data is sent to “ThingSpeak” using internal Wi-Fi of RPi.
b) Registration is done on the ThingSpeak Cloud and channel is being created for collection of the data. The Data from the sensors is sent to the Cloud where it is displayed graphically.
c) A mobile app in the end user’s mobile device then talks to the cloud by connecting to it and the information regarding the health and wellbeing of animal is known to the user.

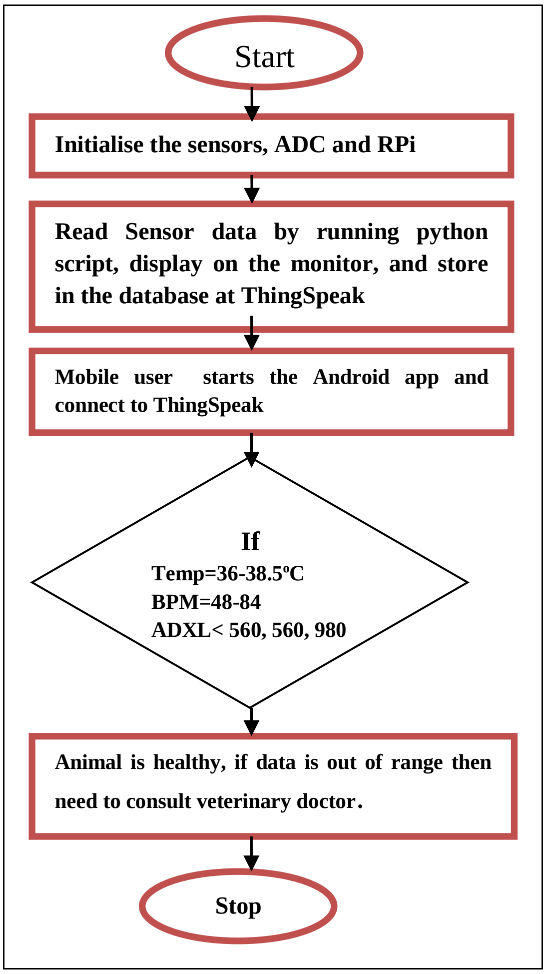

Fig. 5: Flow Diagram of the IoT based Smart Animal Health Monitoring System

5.3 Results Obtained

The Codes when run on raspberry Pi have given the measured body temperature in degree Celsius and degree Fahrenheit, heartbeat in Beats Per Minutes(BPM) and rumination in terms of movement in X, Y, Z-directions. The displayed data at the console are forwarded to ThingSpeak cloud by Wi-Fi based on IEEE 802.11 standard .User can access those data from anywhere using internet and android app on their mobile. By careful observation of the available information at cloud of ThingSpeak user can easily diagnose the health status of animal.

a) b)

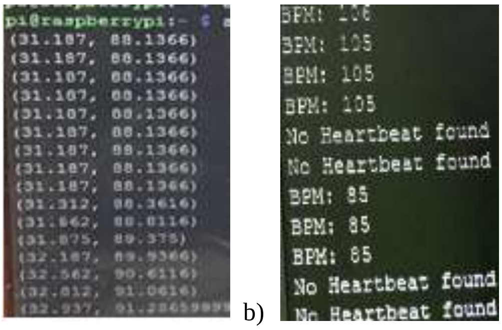

Fig .6: a) Console output of body temperature sensor b) Console output of Heartbeat sensor

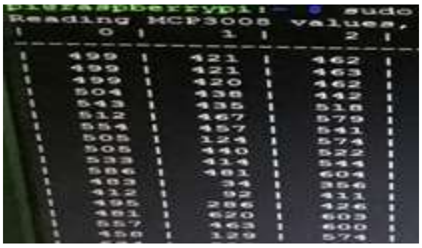

Fig. 7: Console output of Rumination sensor
(Here 0: X-axis, 1:Y-axis, 2:Z-axis)

Fig. 8: Data of temperature sensors from Raspberry Pi 3 to ThingSpeak

6. Conclusion and Future Research

The core goal of the research paper is to design and develop "a prototype of an IoT based smart animal healthcare monitoring system"**.** The developed system is capable of real-time monitoring the body temperature, heartbeat and rumination with the help of Raspberry Pi3 (with inbuilt Wi-Fi) MCP30008 (analog to digital converter), body temperature sensor, heartbeat sensor and rumination sensor. The displayed data at the console are forwarded to ThingSpeak cloud by Wi-Fi based on IEEE 802.11 standard .User can access those data from anywhere using internet and android app on their mobile. By careful observation of the available information at cloud of ThingSpeak user can easily diagnose the health status of animal. If there is any abnormality he can consult veterinary staff and treatment can start at initial stage which can be cured easily reducing the treatment cost.

The research work could further be enhanced by determining the QoS parameters of the obtained results. The developed novel prototype may also be implemented with the help of Raspberry Pi 0, as its quite cheap compared to raspberry pi3. The practical implementation can be done on mass scale in different cow shelters. Moreover we will use GSM module also to send text to farmers and owners for real time monitoring of animal health.

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