1.1 BACKGROUND AND MOTIVATION

India is an agrarian country. Farmers in India have cattle in addition to their farms at large. India, in spite of rearing 43.6 million cattle (16.5% of the world population), on its conducive land; has lower average yield of 1,155 liter per animal an year(8.4% of the global yield) as compared to other countries like Netherland, New Zealand [1]. Efforts taken by the government like the white revolution led by Dr. Verghese Kurien also proved to be inconsequential with time.

The botches in this sector led to think about the technology penetrations in this field in India; which were found quiet shallower given Illiteracy, unavailability of internet, expensive imported systems, traditional approach, administrative negligence towards rural awareness etc.

1.2 AIM OF THE PROJECT

The project aims to develop an interdisciplinary comprehensive platform to interpret the meaning of the physiological parameters for milking animals corresponding to their average milk yield and establish a relationship between them [2]. An IoT based platform would provide a daily and in-depth analysis of the dairy animal. Data over a specific period of time can be assessed by the monitoring system and suggest improvements to alter the handling of animals, diet, etc.

1.3 PROPOSED SYSTEM AND FEATURES

Milking station where the cattle are milked is used to monitor the parameters. When the cattle are milked, they are stationary. Hence by staging their path to milking stations, their physiological parameters can be assessed through sensors.

Outputs from web cameras fixed at various positions would help to note height, width and breadth of the cow. Lameness can be assessed by the hunch cows get when they stand on a plane surface. Both these parameters can be monitored employing digital image processing.

Temperature can be measured internally as well as superficially. When the cow enters the station, daily locomotion database is logged in system over Wi-Fi interface. The milking machine would automatically provide the data about the quality and quantity of milk [3]. This data obtained by internetworking the sensors is logged into cloud over internet and analyzed by remote server. It suggests the inference about milk yield in correspondence to the health of cow, and proactive solutions to improve further results.

1.4 SCOPE

The project incorporates the combination of sensor interfacing and cloud computing for implementing the Internet of things. Given that system is to be deployed on body of livestock, constraints like weight, electrical isolation, long life for batteries is important. Electronic Product design and base station reliability are major concerns while end to end testing.

2.1 LITERATURE REVIEW

Animal activity monitoring is important, as the animals in question are uncontrolled livestock; and their daily activities and problems affect the betterments in milk yield efficiency.

Animal Activity Tracking: Though the dairy farm areas are restricted and secured, cows may suffer from partial injuries, fatigue, fever through daily walk of 7-8 km. The databases depicting hourly walking database, body temperature logs prove useful to attend the diseased in time.

Health Monitoring and postures: Body dimensions, Weight, moisture contents in excrete vary significantly during estrus, pregnancy, diseases like Bovine anemia, cryptosporidiosis. Lameness in animals prohibiting them from normal movements and grazing

Expert's advice: For expert's advice, cattle are to be taken to district health care centers due to lack of infrastructure in rural areas, economically nonviable for most farmers. System privileging experts to interact and update system remotely and automatically prompt the suggestions and alerts are necessary. Present market products are expensive and only track the locomotion and estrus of the cattle neglecting factors like lameness and body weight. Hence, the farmers can hardly interpret the relation between the physiological disorder and the reduction in milk production.

Daily walking behavior: Walking speed, rhythm compared to the group and activity compared to group defines the condition of cow; useful to detect estrus, pregnancy.

Animal weight: Important factor in determining the progress of a pregnant, lame cows

Body temperature: Defines estrus, fever

Lameness: Partial to severe changes in walking postures prohibiting grazing, weight loss, and hoof injures.

Major monitoring parameters are:

2.1.1 Locomotion

Due to sickness, a cow will be motivated to lie down in order to rest and enhance the healing process by minimizing the consumption of body energy reserves [4]. However, lying down may cause uncomfortable or painful feelings because of a painful udder, which can limit the lying time [6].

2.1.2 Temperature

Grazing cows tend to walk around 7-8 km. Though the dairy farm areas are restricted and secured, cows may suffer from partial injuries, fatigue, fever etc. through the day off wandering. In such cases, the databases depicting physical locomotion, body temperature logs prove useful for the management to attend the diseased in time.

2.1.3 Body Weight and physical dimensions

Body dimensions, Weight, moisture contents in excrete vary significantly during estrus, pregnancy, diseases like Bovine anemia, cryptosporidiosis etc. Cows losing more BW in early lactation conceived with greater likelihood than those with a greater BW loss [4].

2.1.4 Lameness

Lameness is the change in cattle posture and gait due to health issues limiting its locomotive capabilities. It is monitored in terms of locomotion score:

Locomotion scoring is a 5-point system based on both gait and posture.

- Normal: The cow is not lame; the back is flat.
- Mildly lame: The back is slightly arched when walking.
- Moderately lame: The back is arched when both standing and walking. The cow walks with short strides in one or more legs.
- Lame: The truly lame cow will bear some weight on the affected foot.
- Severely lame: The back is arched; the cow refuses to bear weight on the affected foot and remains recumbent.

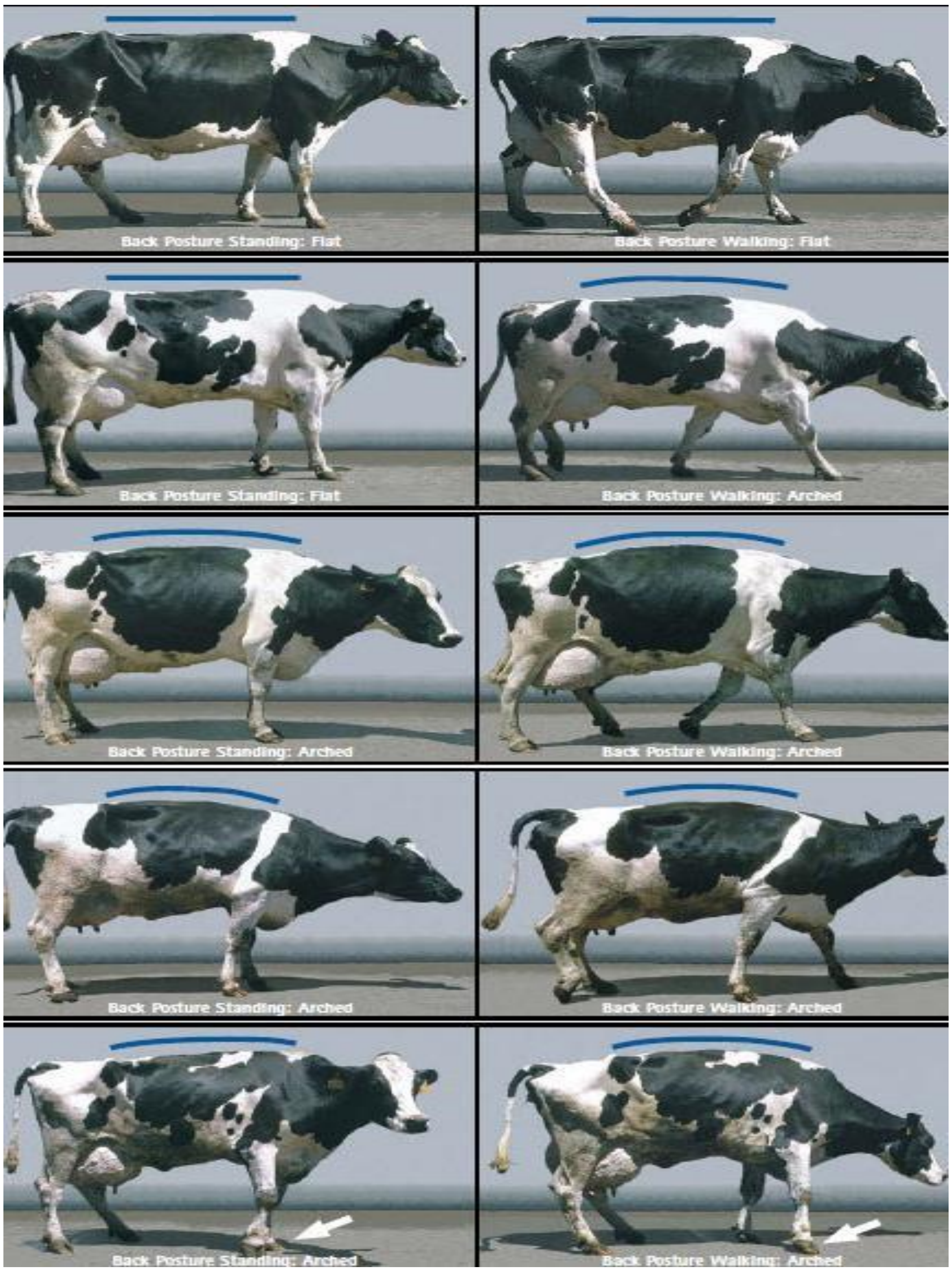


Fig 2.1 Stages of lameness for locomotion scores 1-5 [Courtesy: Zinpro]

2.2 CURRENT MARKET REVIEW

- There are various companies which provide cattle monitoring systems. They only track the locomotion and estrus of the cattle. Thus factors like lameness and body weight are left out. Hence, the farmers won't understand the relation between the physiological disorder and the reduction in milk production.
- These systems use GPS trackers and other costly components making the system beyond the reach of the common Indian cattle farmer. The cost of these systems may go upto Rs 500,000 (Consulted to a farming expert).
- The functioning of these systems is complicated and difficult to understand for the workers.
- No relation established between the disorders and production variation.

Physical components of IoT based cattle monitoring system is divided into two parts: Wireless Activity Tracker (WAT) device and Base Station. The CPU of the WAT device is ESP 8266 micro controller, embedded on wemos D1 mini pro wireless IoT module. The CPU acquires the data from the inertial measurement unit (IMU) based pedometer and temperature sensor. Acquired data is auto logged on cloud daily.

The base station consists of an ARM based development board, Raspberry Pi for image processing and data transmission to the cloud. A camera is programmed for automatic image capturing by detecting cow. Image processing algorithms [6] are applied to these images for calculation of degree of lameness of the cow. A load cell is calibrated as a weight sensor is installed for calculation of weight of the cow.

3.1 BLOCK DIAGRAM

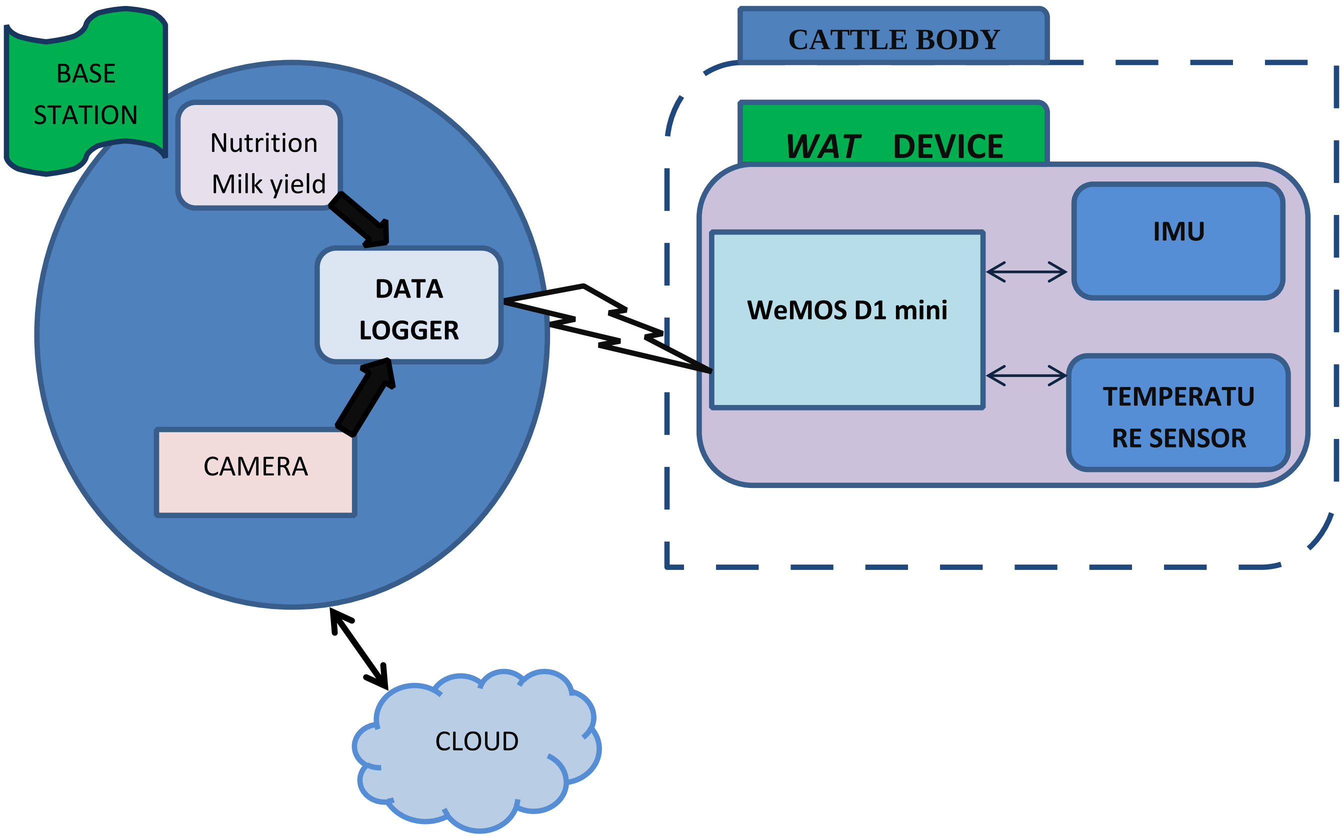


Fig 3.1 Block diagram of IoT Based cattle monitoring system

- Power Supply Unit: It is a coin cell that provides supply voltage to the WAT device
- IMU: We are using IMU for detecting motion of cattle. Also we will use IMU as pedometer for counting there walking distance.
- Temperature sensor: Temperature sensor is used for monitoring body of that cattle so we can get about its diseases.

- Nutrition: The fodder given to the cow for eating is mixture of multiple nutritional foods.
- Milk yield: The milk yield in liters is recorded. This is helpful in analyzing the cow's health
- Camera: Camera will be used for image processing for detecting lameness.
- WeMos D1 Mini: This will be processing unit on WAT device. This is compact in size, less power consuming and it has inbuilt Wi-Fi module.
- Base Station: Base station has a PC and Wi-Fi module.

3.2 SYSTEM DESIGN

3.2.1 IMU

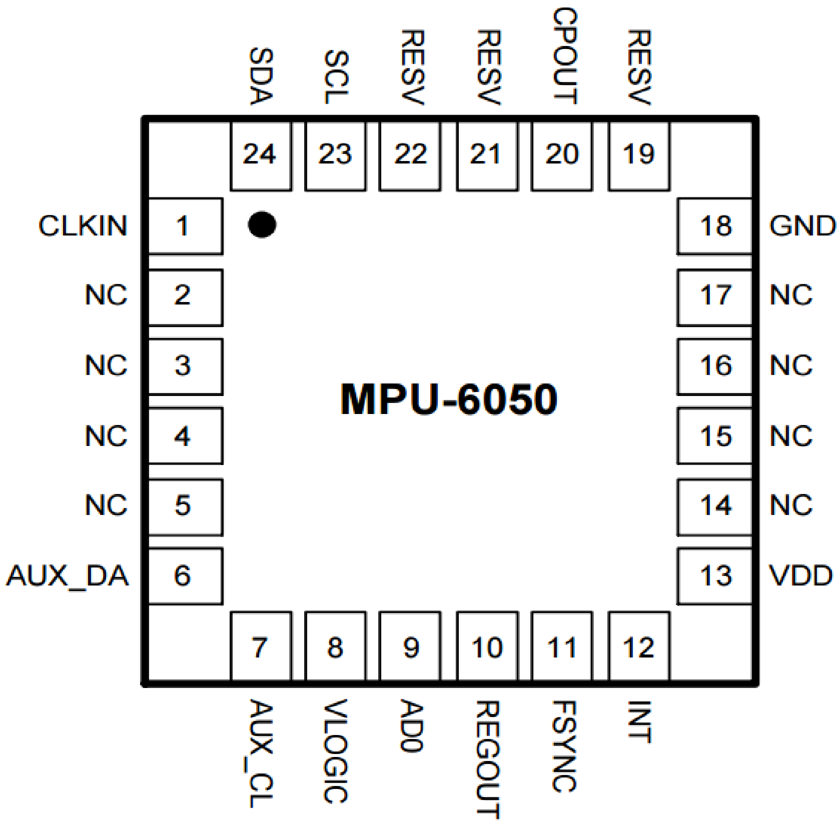


Fig 3.2 MPU 6050 6DoF Inertial Measurement Unit

Inertial Measurement Unit (IMU) is device use for determining changes in position of an object. It consists of accelerometer, magnetometer, and gyro meter. It gives co-ordinate in units of roll, pitch and yaw. We can program it and use it as a pedometer.

3.2.2 ESP 8266

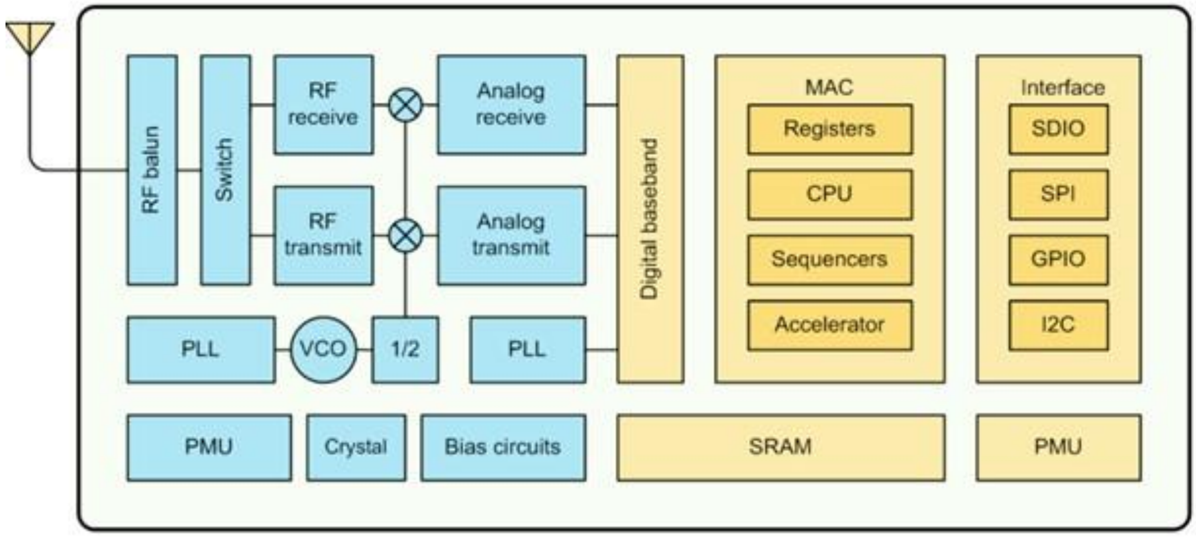


Fig 3.3 ESP 8266 internal block diagram

ESP8266EX offers a complete and self-contained Wi-Fi networking solution; it can be used to host the application or to offload Wi-Fi networking functions from another application processor. When ESP8266EX hosts the application, it boots up directly from an external flash. In has integrated cache to improve the performance of the system in such applications. Alternately, serving as a Wi-Fi adapter, wireless internet access can be added to any micro controller based design with simple connectivity (SPI/SDIO or I2C/UART interface). ESP8266EX is among the most integrated Wi-Fi chip in the industry; it integrates the antenna switches, power amplifier, low noise receive amplifier, filters, power management modules, it requires minimal external circuitry, and the entire solution, including frontend module, is designed to occupy minimal PCB area. ESP8266EX also integrates an enhanced version of ten silica's L106 Diamond series 32-bit processor, with on-chip SRAM, besides the Wi-Fi functionalities. ESP8266EX is often integrated with external sensors and other application specific devices through its GPIOs.

Specifications

- 802.11 b/g/n
- Integrated low power 32-bit MCU
- Integrated 10-bit ADC
- Integrated TCP/IP protocol stack
- Integrated PLL, regulators, and power management units
- Supports antenna diversity
- WiFi 2.4 GHz, support WPA/WPA2
- Support Smart Link Function for both Android and iOS devices

- SDIO 2.0, (H) SPI, UART, I2C, I2S, IR Remote Control, PWM, GPIO
- Deep sleep power <10uA, Power down leakage current < 5uA
- Wake up and transmit packets in < 2ms
- Standby power consumption of < 1.0mW (DTIM3)
- +20 dBm output power in 802.11b mode
- Operating temperature range -40C ~ 125C
- FCC, CE, TELEC, Wi-Fi Alliance, and SRRC certified

3.2.2 DS 18B20

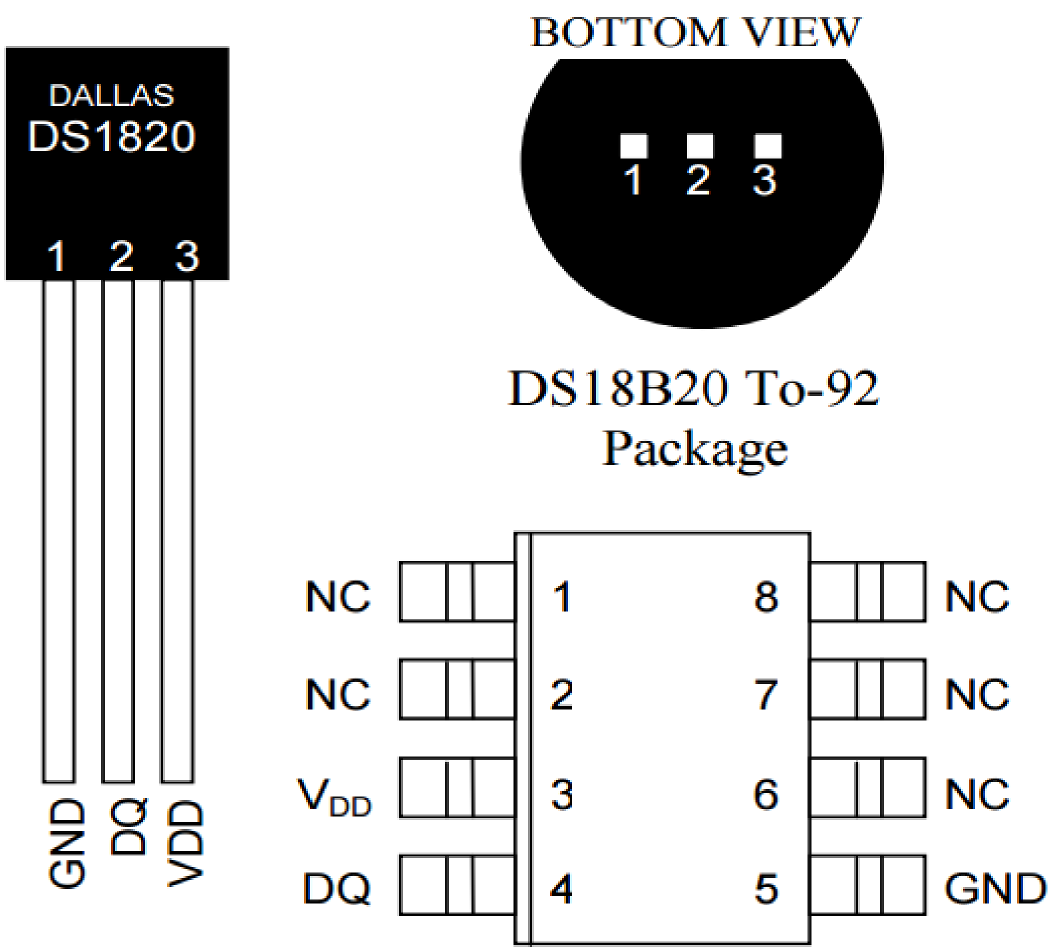


Figure 3.4 DSB18B20 package and pin diagram [Courtesy: Dallas semiconductors]

Specifications

- Unique 1-Wire interface requires only one port pin for communication
- Multidrop capability simplifies distributed temperature sensing applications
- Requires no external components
- Can be powered from data line. Power supply range is 3.0V to 5.5V
- Measures temperatures from -55°C to +125°C. Fahrenheit equivalent is -67°F to +257°F
- ±0.5°C accuracy from -10°C to +85°C
- Thermometer resolution is programmable from 9 to 12 bits
- User-definable, nonvolatile temperature alarm settings

3.2.4 Graphical User Interface (GUI):

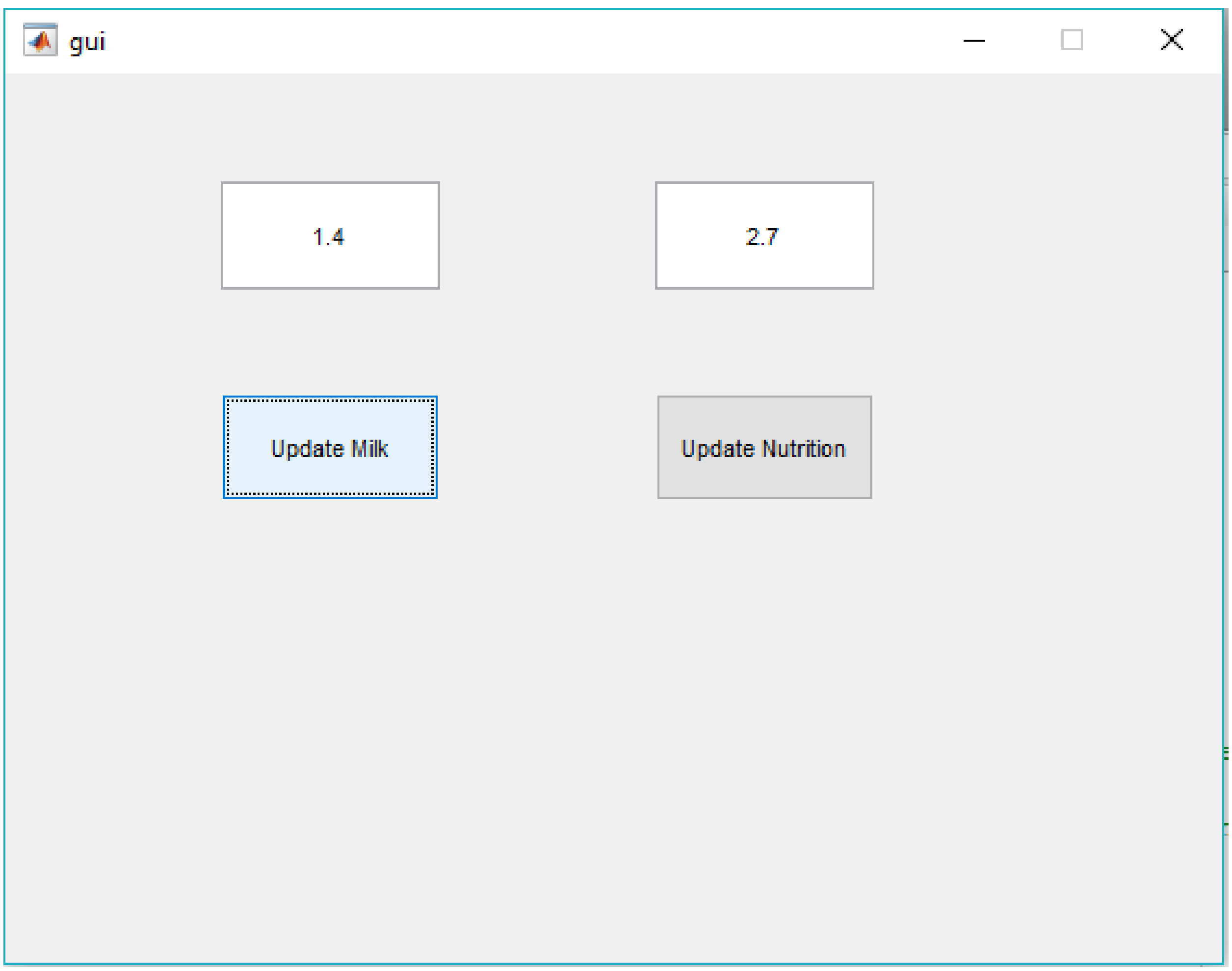


Figure 3.5 GUI design [MATLAB]

A GUI is provided to the user for providing data regarding nutrition and the milk yield. This data is uploaded on the IoT cloud. A systematic database is created. This database can be accessed by the experts and veterinary doctors for analysis. Nutrition of the cow helps in analysis of the food intake by cow. The milk yield is helpful for analysis and the database can be exploited for use. It is designed in MATLAB. Data is uploaded on the IoT cloud in real time.

3.2.5 Web Camera

We use a camera for detecting the lameness of the cow. We take the side view image of the cow. We need a camera with good resolution to taking good quality images. Images with good resolution will give accurate image processing results.

Specifications

- Brand: QHMPL
- Type of sensor: CMOS
- Model Id: QHM495LM
- Connectivity: USB
- Has Night Vision: Yes
- Video Sensor Resolution: 0.5 megapixel
- Still Image Sensor Resolution: 10 MP

4.1 BUILDING BLOCK AND ALGORITHM DESIGN

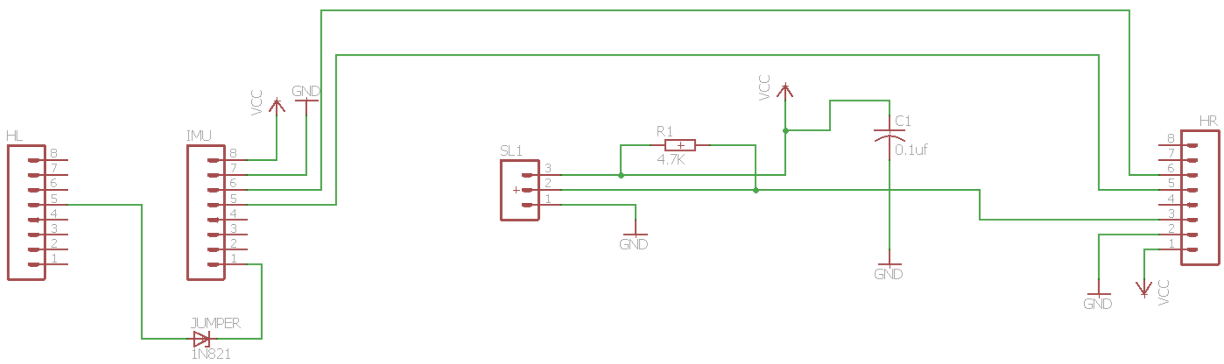


Fig 4.1 Block schematic for ESP 8266 WAT device (EAGLE CAD)

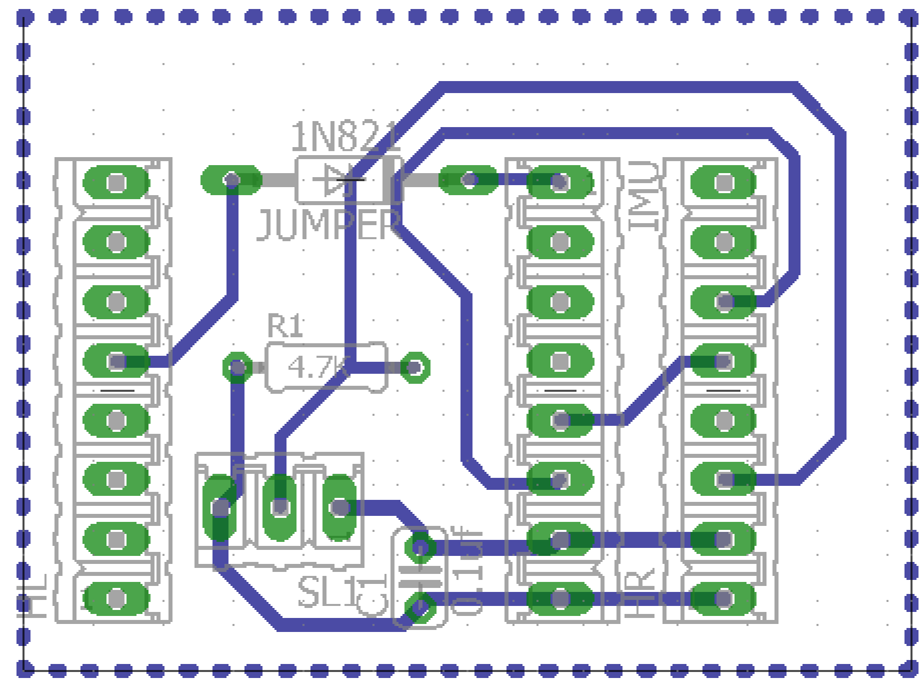


Fig 4.2 PCB layout for ESP 8266 WAT device (EAGLE CAD)

Algorithm for Lameness detection applying DIP

- Start
- Acquire image
- Preprocess image
- i) Convert into gray scale
  ii) Apply median filter for salt and pepper noise removal
  iii) Convert to black and white
  iv) Pad with additional borders
- Apply angular planning designed mask for HPF action
- Mask the borders translated as edges
- Obtain the edge detected image
- Obtain upper edge of image to represent the back of milking animal
- Prune the unwanted section and obtain the portion of back depicting the lameness
- Obtain the equation of the back by using the concept of curve fitting.
- Obtain the standard deviation parameter from the equation of the back.
- Compare the obtained standard deviation with the database to obtain the degree of lameness.

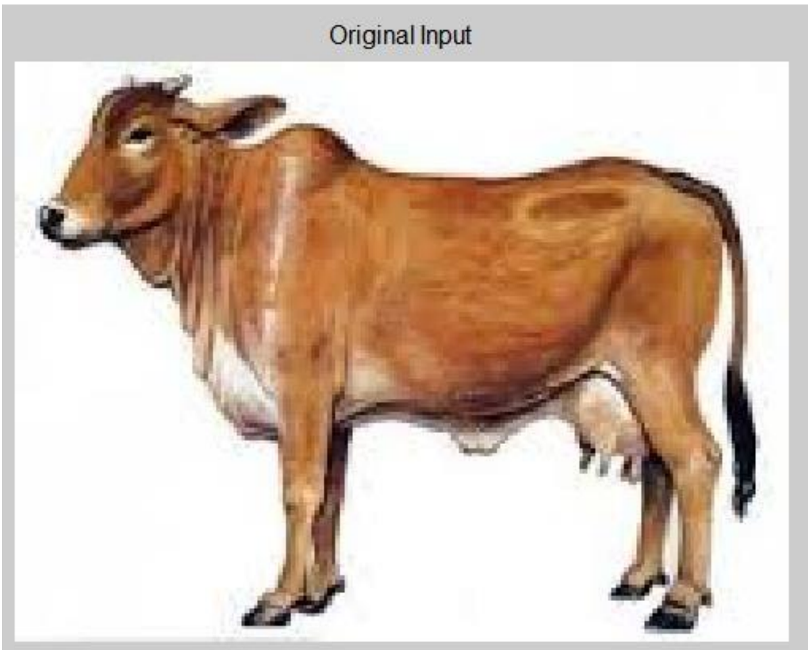


Fig 4.3 Input image

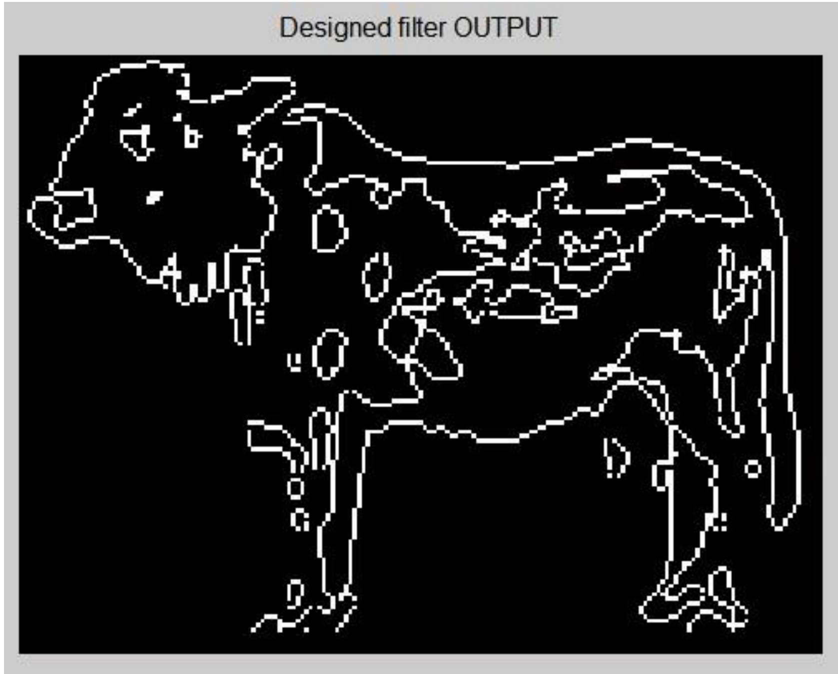


Fig 4.4 Designed planar HPF Edge detection (MATLAB)

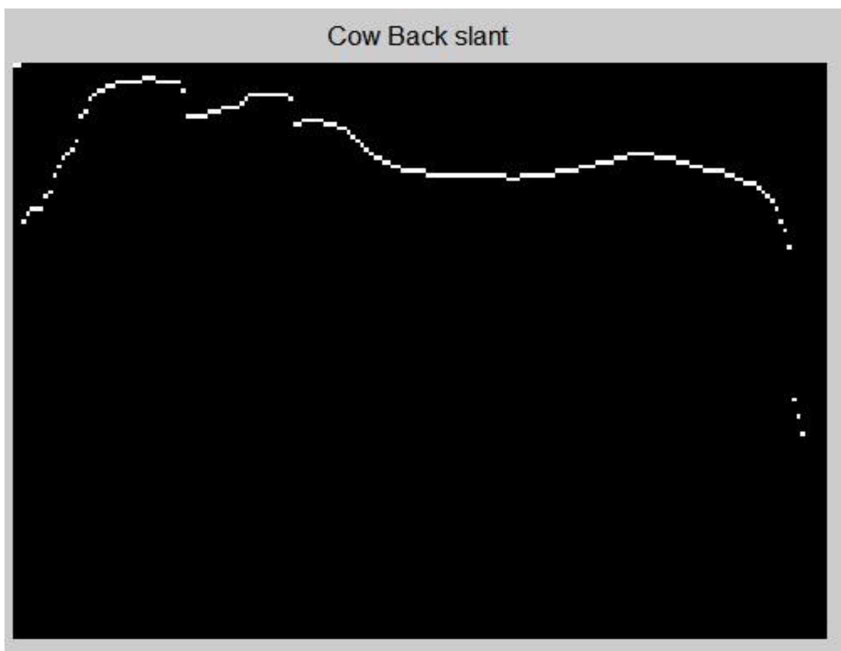


Fig 4.5 Edge retrieval for Lameness detection (MATLAB)

4.2 COMPONENT DESIGN

Presented system proposes a solution to the problems faced while monitoring cows. A detailed analysis report can be achieved and the parameters can be analyzed.

- **Locomotion Score:** A pedometer is used to track the number of steps taken by the cow. Hence, the total distance covered can be calculated.
- **Temperature Sensor:** A temperature sensor is used monitor the temperature of the cow from time to time.
- **Camera:** A camera is used to determine the lameness of the cow. The hump on the back of the cows is calculated by image processing algorithms.

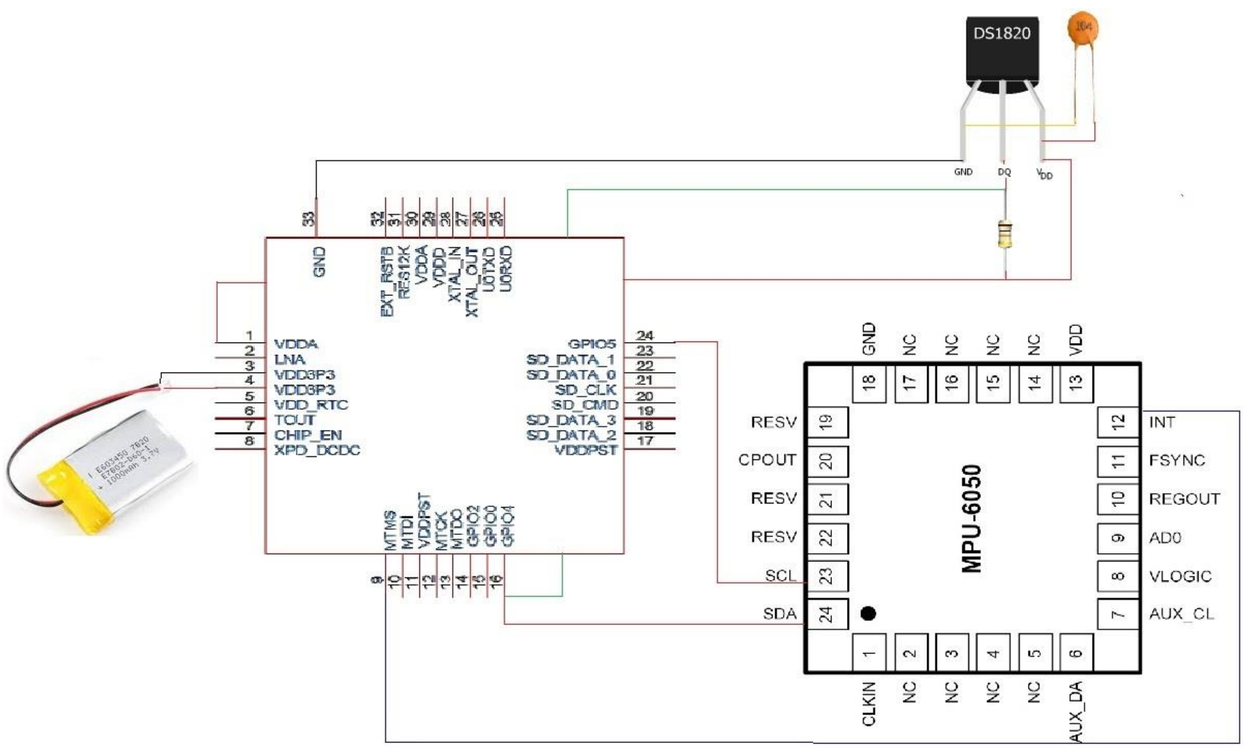


Fig 4.6 Circuit interconnect diagram (WAT device)

4.3 RESULTS

4.3.1 Locomotion

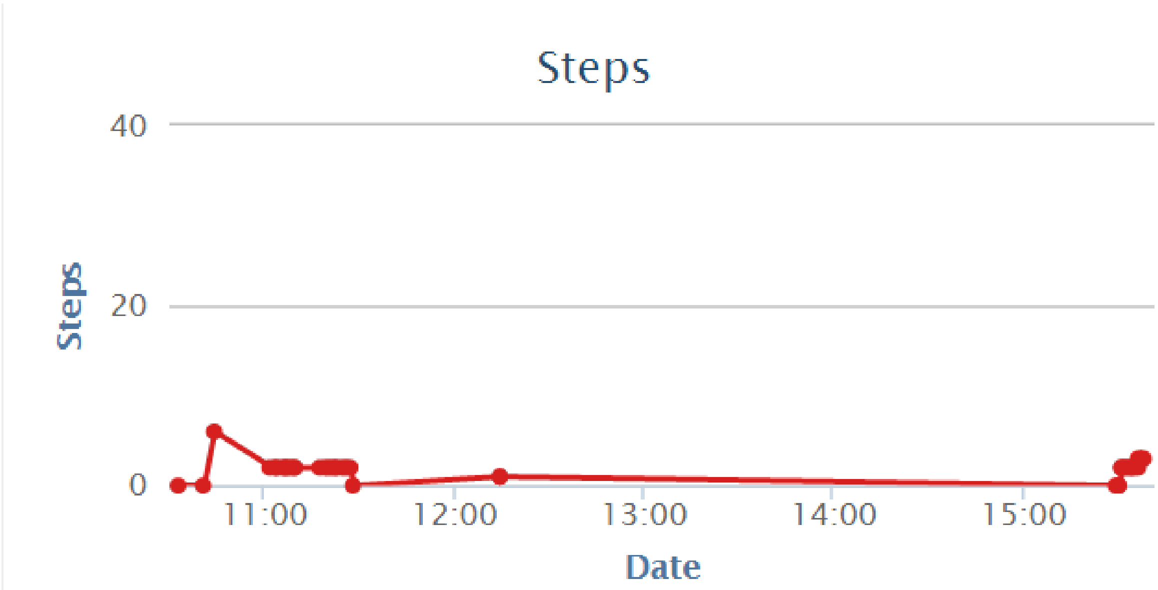


Fig 4.7 Real time update on remote IoT cloud for Steps walked by cow

The pedometer gives us the number of steps taken. The distance could be found out by taking the product of stride length and number of steps taken. The number of steps. A database of the number of steps taken could be used to analyze the pattern of change in walking style of the cow. A decrease or increase in number of steps indicates various symptoms for various problems. Increase in steps count is usually considered as a good sign. This indicates that the cow is healthy and there is no physical disability it is facing. A decrease in step count indicates that there may be a problem with the cow's feet or hoofs. It also is an indicator of any disease or occurrence of pregnancy. This can be confirmed by analyzing locomotion with various other parameters for confirmation.

4.3.2 Temperature

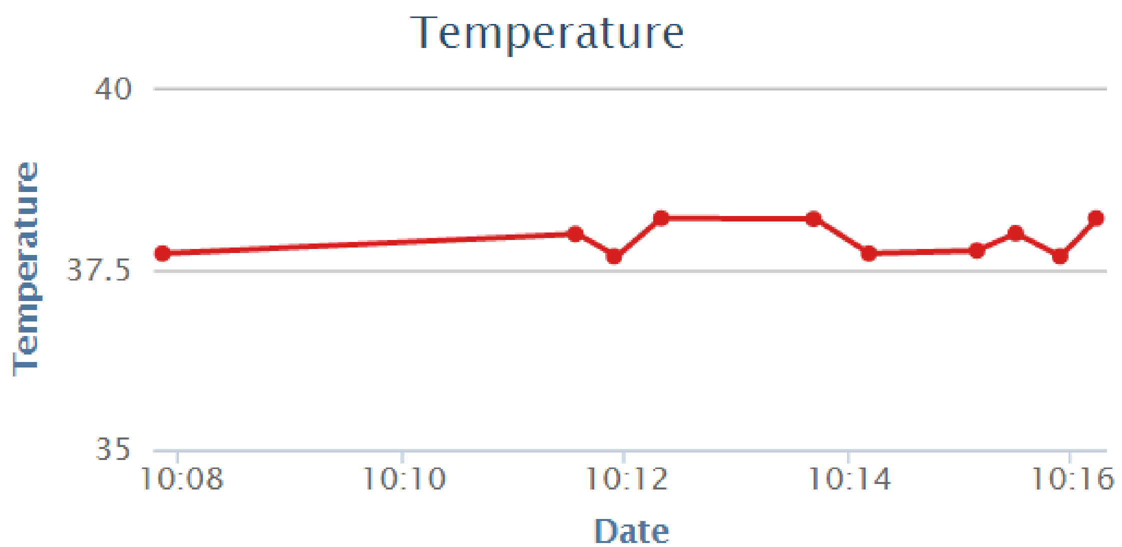


Fig 4.8 Real time update on remote IoT cloud for temperature

A temperature log is necessary for analyzing various diseases like fever. An hourly log can be useful for monitoring the fever. Estrus of the cow can also be detected using the temperature log. A spiking will be seen. The 16MB of flash and 512KB of EEPROM can be exploited for storing readings of more than 4 days.

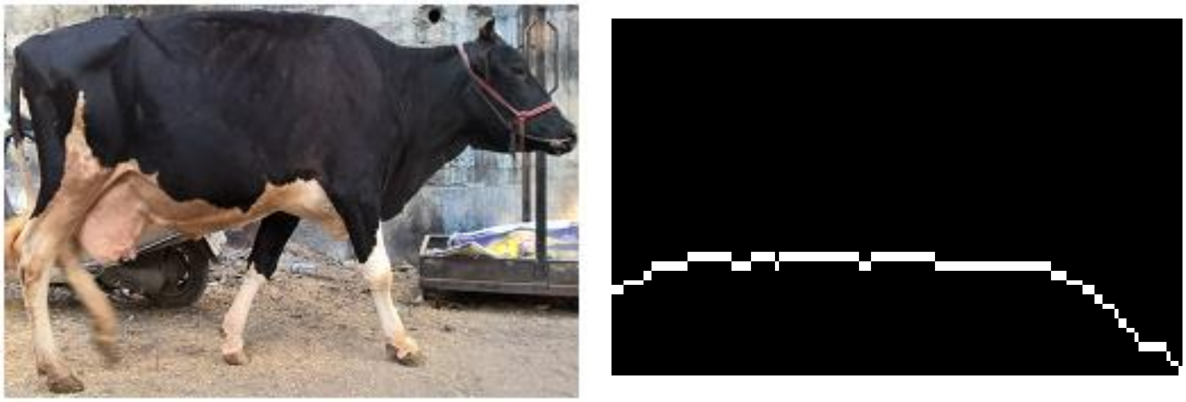
4.3.3 Lameness

Lameness has 5 categories:

- **Normal:** Normal walking. Spinal cord is erect.
- **Mildly Lame**: Spinal cord starts to bend. Slight limping.
- **Moderately Lame:** Spinal cord curve is visible clearly. Limping is evitable.
- **Lame:** Back is arched. Hardly able walk**.**
- **Severely Lame:** Back is totally arched. Unable to walk.

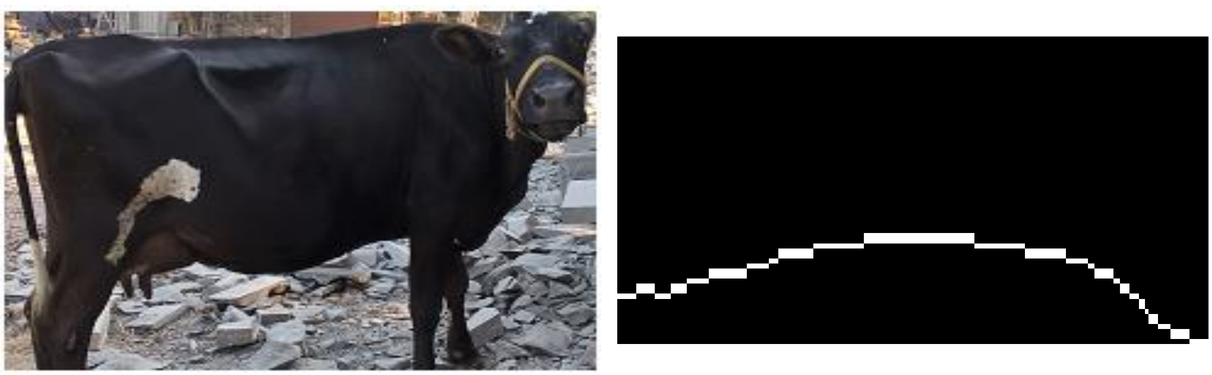
Lameness affects:

- **Milk yield:** The milk produce decreases exponentially.
- **Locomotion:** Locomotion decreases as lameness increases.
- **Food intake:** Food intake decreases



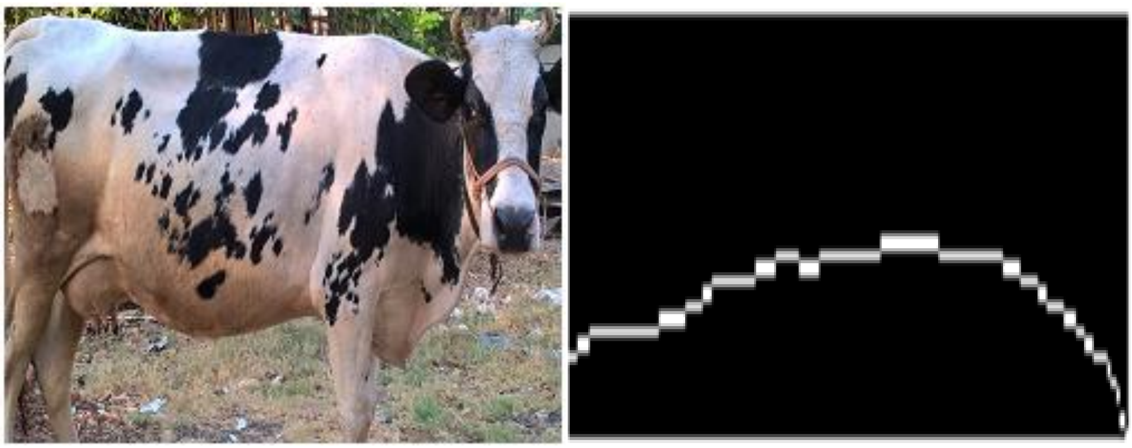
(a)

(b)



(c)

(d)



(e)

Fig 4.9 Edge retrieval for Lameness detection (a) Stage 1 lameness, Pointer= 0.3873 (b) Stage 2 lameness, Pointer= 0.3856 (c) Stage 3 lameness, Pointer= 0.3774 (d) Stage 4 lameness, Pointer= 0.3348 (e) Stage 5 lameness, Pointer= 0.2618

4.3.4 Nutrition

Nutrition is the most important parameter in determination and analysis of milk produce of the cow. The nutritional contents in the cow's fodder determines the quality and quantity of milk. The cow mainly graze on grass in the field. This may not provide them with complete nutrition. Hence, some extra food ingredients need to be added in their fodder. These food ingredients may be locally produced like cotton seed oilcake and gram flour or factory produced. Nutrients like potassium and other minerals can be obtained through such extra additions in fodder. The data regarding the fodder is updated on the IoT cloud. This data is indexed with other parameters of the cow.

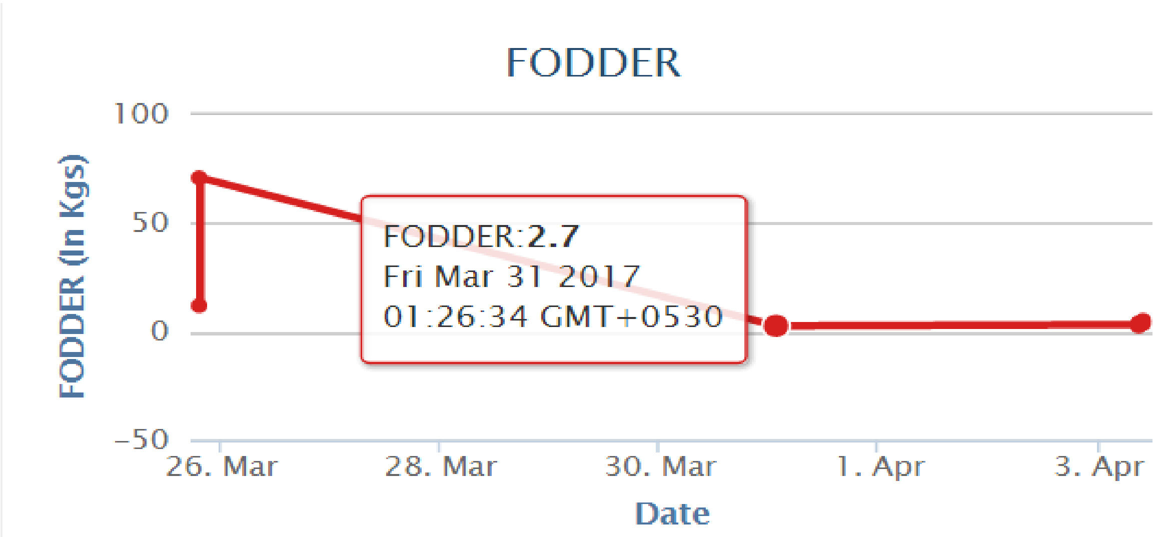


Fig 4.10 Update on remote IoT cloud for Fodder fed to cow

Mixture of nutritious ingredients in designed quantity is fed.
Fodder includes:

- Cotton seed oilcake
- Gram flour
- Dry grass
- Sprouted wheat

4.3.5 Milk Yield

The milk yield of the cow is the measure of the cow's productivity. The quality and quantity are important aspects in analyzing the cow's physiology. The quantity (in liters) is recorded via the GUI. A database is prepared on the IoT cloud. This database is indexed with the cow's other parameters. The quality of milk i.e. the thickness is considered for analyzing the digestion system of the cows. More the thickness, better is the digestion of cows.

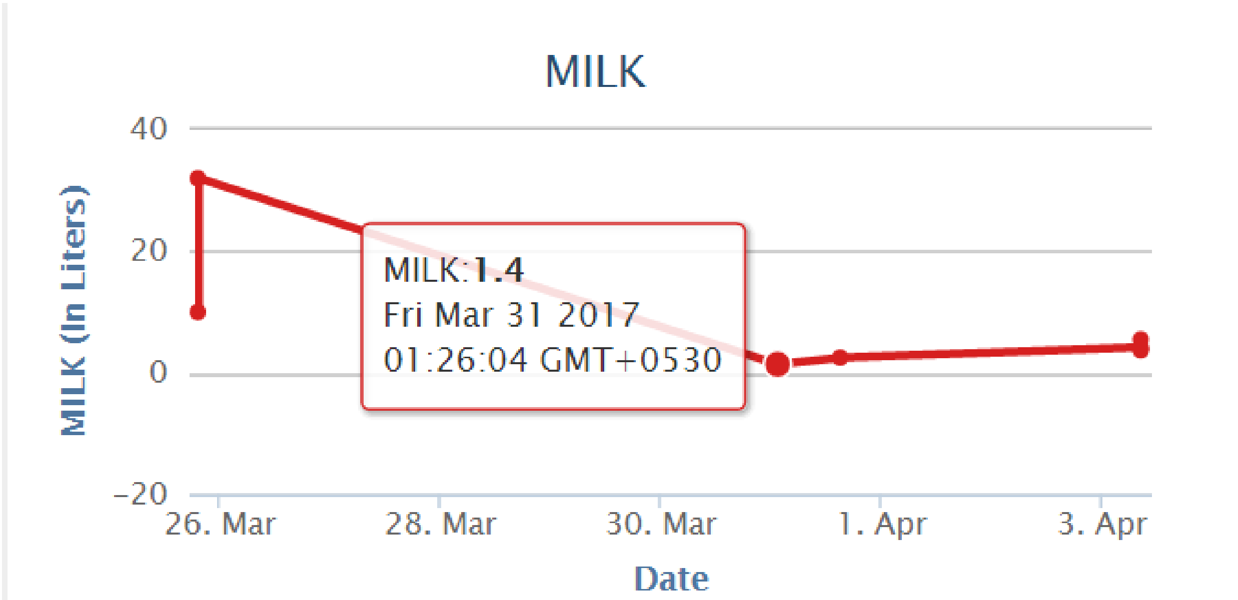


Fig 4.11 Update on remote IoT cloud for milk yield by cow

The change in milk yield could be a result of one or multiple parameters such as:

- Fever
- Lameness
- Pregnancy
- Estrus
- Aging
- Physiological disabilities

5.1 FUTURE SCOPE

- Expand the scope beyond cows to buffalos and goats.
- Use GPS based tracking
- Detection of Estrus and calving
- Provide the farmer with hourly updates of cellphones via SMS.
- Make the system affordable for a cattle farm with less than 40 cows.

5.2 CHALLENGES FACED

- **Statistical data collection**
  Very little data was available on Indian cows. Most paper publications were regarding hybrid jersey cows. Agriculture universities had very little database regarding the diseases and behavior of cows.

- **Implementation of the system on cows**
  Finalizing sensors for capturing data were a big challenge. The sensors chosen needed to have a very high sensitivity and rigid in nature. The placement of sensors was major challenge. The sensors had to be placed in such a way that it would give the exact readings. The temperature sensor had to be placed near the throat section of the cow. It was difficult to ensure that the temperature sensor was always in contact with the skin. A strong casing design was needed so that any external damage could be avoided.

- **Calibration of instrumentation for cows**
  The stride length of cows differs. Hence, the values of roll, pitch and yaw change consequently. A database had to be formed for analysis and setting of threshold value for the step count of cows.

- **Background color selection for Image processing**
  The HF and jersey cows are covered with black and white patches. After conversion to Black-white image, the regions became unrecognizable. During edge detection, the background region and the white region of cows merged and the edges could not be identified.

- **Processing and analysis**
  The database was formed after implementation of system. The data figures of temperature, step count, nutrition and milk yield had to be interrelated. The data had to be sent to the experts for analysis. Due to imperfections, some irrational value had been stored. Hence, the database for some duration were missing.

5.3 CONCLUSION

A detailed study of the Indian cattle farm was conducted. Various parameters like lameness and locomotion are the parameters which affect the cow’s milk production. Sensors to analyze these parameters were found out. An IMU is programed as a pedometer to count the number of steps taken and thus the locomotion. A camera is used to take the images of the cow. These images are further analyzed by using Digital image processing techniques to detect the lameness in cows. A temperature sensor implanted in the ear of the cow would provide a continuous database of the cow’s temperature measurements. Hardware and software design of the WAT device and station are finalized. This system would provide a complete assessment of the cow on a daily basis and provide the necessary changes that are to be made in the lifestyle of the cow in order to increase the milk production.

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