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A Sensor-Based Forage Monitoring of Grazing Cattle in Dairy Farming

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Abstract

In this proposed work, the feeding behavior of cow is analyzed to monitor its health condition, through the detection of three most common events of grazing activity such as chew, bite, and chew–bite. A healthy cow should have a good means of chew, bite, and chew–bite habits. Hence, an unhealthy cow can be easily identified by its grazing activities and treated immediately. Here, a wearable and compact device is developed, which is used to monitor the grazing events. The device consists of Arduino uno, Accelerometer sensor, Wi-Fi module, and a battery for power supply. This helps the cattle owners to monitor the cattle condition at remote distance via wireless communication. The device was placed on 30 cows and 65 real-time datasets were recorded in which 30 datasets indicated bite event, 26 datasets indicated chew event and 14 datasets indicated chew–bite event and it was verified.

Keywords
Accelerometer sensor, Arduino uno, rumination and chew–bite, Wi-Fi module.

Animal management is most important in a country like India with agriculture and animal husbandry as key pillar of its economy. Health of animals is as important as the health of humans. The adverse thing is that, much importance is not given to the animal health. Especially the health of cattle should be taken into account, because it is always a part of human life. Animal husbandry is one of the core branches of agriculture sciences which deal with care, breeding, and management of the animal. Animal husbandry sector plays a crucial role in supplementing the income of farmers. Animal husbandry department plays a major role in providing veterinary health care and improving the genetic production potentialities of livestock and poultry reared in the state.

Animal disease observation is an integral part of animal husbandry and veterinary services, through which veterinarians can diagnose, monitor, control, and eradicate existing and emerging diseases in livestock's. This change has resulted in demand for technologies that can reduce costs and labour inputs while increasing farm productivity. This is mainly achieved through the use of farm automation and advanced techniques. The use of appropriate sensors will be vital in the development of the next generation of health monitoring system for dairy animals. Such a system will allow the automatic identification of animal health events, thereby increasing productivity while reducing animal health inspection and long-term animal healthcare costs.

Grazing activity is composed of all the three events: bite, chew, and chew–bite. Rumination activity is composed only of chew event. Bite includes saving of forage and chew includes bringing the food back to its mouth and crushing of forage. The chew–bite results from the superposition of chewing and biting activities but made with the same jaw movement (Deniz et al., 2017). All these three events are necessary to determine the health of the cattle.

The main goal of the work is to determine the health of the cattle. This is achieved by diagnosing the feeding behaviour of the cattle. One of the most accepted ways to perform monitoring of ruminant feeding is through the detection of the three most common events of grazing activity: chew, bite, and chew–bite. The detection and classification of these three types of events is necessary for accurate monitoring of the diet of animals (Deniz et al., 2017). A healthy cow should have a good means of chew, bite, and chew–bite. If a cow does not have a proper means of chew, bite, and chew–bite, then it is an indication that the cow is not healthy. Hence, an unhealthy cow can be easily identified and treated immediately. This saves the life of the animal and also prevents a great loss to the cattle owner.

The objective of the proposed work is to implement a sensor based solution for the health monitoring of the cattle. This system helps cattle owners and other veterinary management to access their information in real time.

In the existing method, microphone has been used to record the sounds of chew, bite, and chew–bite of cattle. Based on the sounds recorded, the above three events are classified. This method may lead to misclassification of the grazing events, because the unwanted sounds also get recorded along with the useful sound (Deniz et al., 2017). The problems in the existing methods have been overcome in the proposed work by giving a sensor-based solution, which makes it convenient to be used by the cattle owners.

The paper is organized as follows: Section "RELATED WORKS" describes the related works carried out. Section "METHODOLOGY" explains the methodology and the hardware device. Section "RESULTS" deals with the results and datasets. Section "DISCUSSIONS" explains the discussions. The project work has been concluded in Section "CONCLUSIONS".

Related works

Here, some of the research activities related to the present work are summarized. In the smart health monitoring system for animals, four sensors are used. They are Temperature sensor, Heart rate sensor, Rumination sensor and Humidity sensor (Patii et al., 2015). Sensors and wireless sensor networks were used for rapid estimation of pasture intake by large number of livestock. It helped in determining the intake of pasture by individual livestock and to obtain sensor data. The sensor data helped to classify the behaviours associated with the amount of pasture eaten (Greenwood et al., 2017). Wireless sensor networks offered the potential for measuring a larger variety of characteristics relevant to grazing livestock. It helped for the phenotyping of large numbers of animals in their commercial grazing environment (Greenwood et al., 2014).

Wireless sensor networks (WSNs) have begun replacing traditional wired sensor networks in many applications. Because many WSN components are not physically tethered to a power source or neighbouring node. WSNs are often deployable in a more versatile fashion over their wired counterparts (Zhen et al., 2015). Automatic recognition of jaw movements in free-ranging cattle, goats, and sheep was performed using acoustic monitoring by placing the microphone in the horn of the animal. In dairy cows, estrus period considerably influences the ruminating and eating activity. Several parameters of ruminating, eating, and motion behavior were identified as important indicators for automatic heat detection in dairy cows (Navon et al., 2012). The chewing sensor (RumiWatch) was used as a tool for heat detection, as it helps to constantly measure behavioural parameters for estrus detection (Zehner et al., 2014).

Changes in rumination and feeding behavior may be the indications of the health problems in cattle. The Rumi Watch System (RWS) is a sensor-based tool that measures the primary behaviors in dairy cattle. The device registers the cow's jaw movements through a pressure sensor (Dinara, 2016). Automatic body condition of cattle was monitored using the pictures captured using normal hand held cameras (Tedın et al., 2013). A zig-bee-based animal health monitoring system was designed to monitor heart rate, body temperature, and rumination with surrounding temperature and humidity (Kumar and Hancke, 2014). Timely diagnosis of infectious diseases in cattle was performed with the help of nano biosensors and advanced molecular biology diagnostic techniques (Neethirajan, 2016).

A collar-mounted recording device was used for studying animal behaviour, but it was sensitive enough to pick up numerous ambient environmental sounds (Lynch et al., 2013). Although the structure of the sensor network nodes is different based on the various applications, the sensor network nodes generally have two components: the node hardware and embedded software. Node hardware mainly consists of the following four parts: data acquisition part (sensor module), data processing part (processing module), data transmission part (wireless communication module), and the power (the energy supply module) (Imam et al., 2015).

It has been noted that the production of milk and work efficiency is affected if the animal fall ill; which in turn affect the animal owner income. The animal mostly falls ill in monsoon season. Weak health and improper treatment of animal directly affect the trade of animal husbandry and agriculture which is the back bone of village life. Due to problem faced by animal owner, special attention needs to be given to animal health monitoring. Thus, it becomes necessary to look out for solution that provides smart health care for animals. The portable health monitoring which could connect to the internet in anywhere and anytime is the only solution to keep animal monitoring.

Methodology

In the proposed work, components such as arduino uno, accelerometer sensor (ADXL335), secondary battery, and a Wi-Fi module (ESP8266) are integrated to set up the hardware device. Accelerometer sensor (ADXL335) is used to sense the jaw movement of cattle in all the three *X*-, *Y*-, and *Z*-axis. Before examination, the *X*-, *Y*- and Z-axis were distorted to the North, East and Down (NED) reference system, so that they indicated the longitudinal (front-to-back, *X*), horizontal (side-to-side, *Y*) and vertical (up and down, *Z*) body axes, correspondingly.

The ADXL335 are low-power, 3-axis MEMS (Micro Electro Mechanical Systems) accelerometer modules with radiometric analog voltage outputs. For analog output accelerometers, the sensitivity is specified at a particular supply voltage and is typically expressed in units of mV/g. The ADXL335 accelerometer sensor can measure at least ±3 G in the *X*-, *Y*- and *Z*-axis. It is suitable for both high-resolution static acceleration measurements such as tilt-sensing and moderate dynamic accelerations from motion, shock or vibration. Wi-Fi module is used for wireless transmission over long distance. The battery used here is lithium-ion battery. These batteries are long life rechargeable secondary batteries. They are lighter in weight and have high capacity.

The device is placed on the livestock to sense the chew, bite, and chew–bite values. The sensed values are received in our system/mobile. The received jaw movements of the cattle are further classified into chew, bite, and chew–bite. The standard communication protocol used here is Hyper Text Transfer Protocol (HTTP). With the help of Wi-Fi technology, the data can be analyzed anywhere and anytime using the HTTP. This information allows herd managers to evaluate the feeding conditions of grazing cattle and make decisions about pasture management. Figure 1 shows the interconnection of accelerometer sensor, arduino uno, and Wi-Fi module in the proposed work.

The main objective is to design and implement an electronic system specifically developed for real-time monitoring of feeding patterns in grazing livestock such as cow. Accurate monitoring of feeding behaviour of free-grazing livestock is necessary to ensure the welfare and health of these animals.

The device is powered with the help of rechargeable batteries. At times, if any power instability occurs during the data transfer, an additional memory is included in the Wi-Fi module to overcome this issue. If the power is interrupted during data transmission, the data transmitted at that particular duration will be stored in the added memory. Once the power becomes stable, the stored data can be retrieved from the memory. The device has a high measurement range. The minimum range is 366 m and the maximum

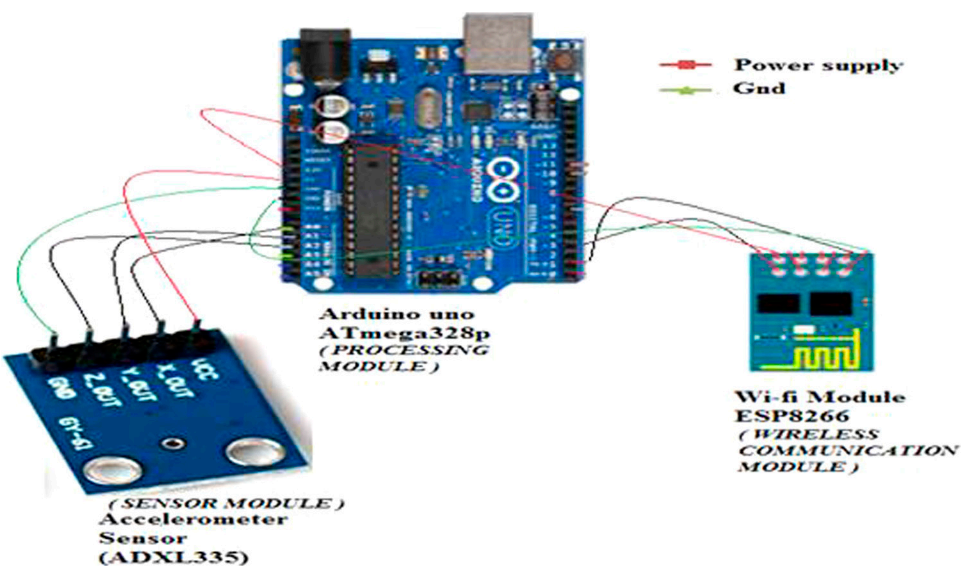

Figure 1: Interconnections between three modules.

range is 479 m. This long coverage range is very useful to the cattle owners, to monitor the cattle in field conditions.

Results

The compact and light weight hardware device is placed on the animal near its collar to avoid disturbance to the animal. The accelerometer sensor (ADXL335) which senses the jaw movement is placed close to its mouth with the help of a wire from the device. The experiment was carried out on 30 cows in a farm at Thoothukudi district in Tamilnadu, India. The chew, bite, and chew–bite graphs are drawn separately for the respective datasets of 30 cows. The datasets are recorded from the cattle during chew, bite, and chew–bite events at different times and analyzed.

Figure 2 shows the developed hardware device before encapsulation. The hardware device consists of Arduino uno, Accelerometer sensor, Wi-Fi module, and a battery for power supply. The device is very compact because of the very few components used in it. The device is very safe and secure to be placed on the animal. It does not cause any harm or disturbance to the animal. Figure 3 shows the placement of the compact device on the cattle while acquiring data.

The device is placed at the collar and the accelerometer sensor is placed near its mouth to sense the jaw movement. A pair of wire connects the hardware device and the accelerometer sensor.

The device is encapsulated so as to protect it from any kind of damage, when used in field conditions. The accelerometer sensor (ADXL335) placed close to the mouth of the cattle for sensing its jaw movement has also been packed in a proper manner, using a water resistant cover. This cover prevents the sensor from moisture and also exposure to other dust particles. The device has been made more compact and it is attached to the belt of the cattle. The device is of smaller in size and also light-weighted. This avoids any kind of disturbance to the cattle and makes it convenient to be used by the cattle owners.

For a single cow, the data was taken during bite, chew, and chew–bite, respectively. Totally 60 datasets are recorded from 30 cows. The reason for why the data were taken at different times for a cow because, a cow does not bite and chew at the same time. First, the cow bites the food and swallows it and then after sometime the cow brings the swallowed food back to its mouth and then chews the food and eats it. During chew event, the cow also makes small bites and they are called chew–bite.

The accelerometer sensor senses the cattle jaw movement in all the three *X*-, *Y*- and *Z*-axis. The sensed three axes details are obtained in the webpage through the Wi-Fi module. For every 5 to 10 sec, 30 sets of data in all the three axes are obtained. Once it is refreshed, 30 more sets of data can be obtained. This process can be repeated any number of times. The data obtained can then be recorded by the user for future use.

Datasets

The device was placed on 30 cows and real-time datasets were recorded. Thirty datasets were recorded during bite event, 35 datasets were recorded during chew event in which 26 datasets indicated chew event and 14 datasets indicated chew–bite event. Hence, 65 datasets were taken totally from 30 cows.

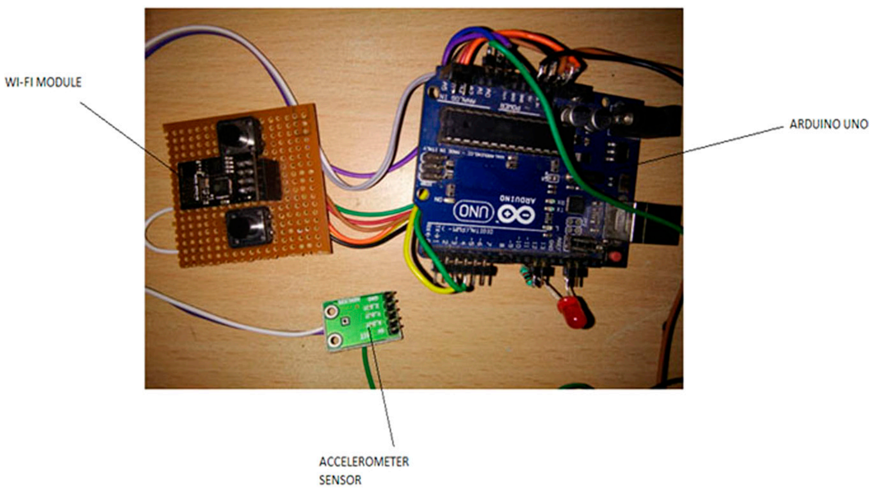

Figure 2: Hardware Device.

Figure 3: Developed compact device on cattle.

From the data obtained, it was observed that for the bite data, the *Y*-axis value was greater than the other two *X*- and *Z*-axis. Also the average value of theY-axis was greater than the other two axes. Similarly for the chew data, the *Y*-axis value was lower than the other two axes. Also the average value of the *Y*-axis was lesser than the other two axes. For the chew–bite data, the *Y*-axis value was in between the other two axes. Also the average value of *Y*-axis lies intermediate of *X*- and *Z*-axis. Figure 4 shows a sample of four bite datasets out of 30 bite datasets recorded.

It can be noticed from the above bite graphs that the *Y*-axis value is higher compared to the values of the other two axes. Figure 5 shows a sample of four chew datasets out of 26 chew datasets recorded.

It can be noticed from the above chew graphs that the *Y*-axis value is lower when compared to other two axes. Figure 6 shows a sample of four chew–bite datasets out of 14 chew–bite datasets recorded.

It is evident from the above chew-bite graphs that the *Y*-axis value is in between the other two axes.

From this we can come to a conclusion that during bite event, the *Y*-axis value will be larger than the values of the other two axes and during chew event, the *Y*-axis value will be lower than the values of the other two axes. During chew–bite event, the *Y*-axis value will be in between the other two axes.

From the analysis of datasets taken, it is noticed that

1. For bite,
   Y–X = positive
   Y–Z = positive
2. For chew,
   Y–X = negative
   Y–Z = negative
   Hence when both *Y–X*, *Y–Z* are positive/negative it is concluded as Bite and Chew, respectively.
3. For chew–bite,
   Y–X = negative
   Y–Z = positive
   (Or)
   Y–X = positive
   Y–Z = negative.

After analyzing the variations between bite, chew, and chew–bite events, the device was continuously placed on four cows and tested. Based on the unique characteristics identified for the three events, the bite, chew, and chew-bite were classified separately from a combination of the three events.

In addition to the above datasets, data were recorded in four more cows continuously for about 2 hr. Figure 7 shows the plot which has the combination of bite, chew, and chew–bite events recorded in four cows.

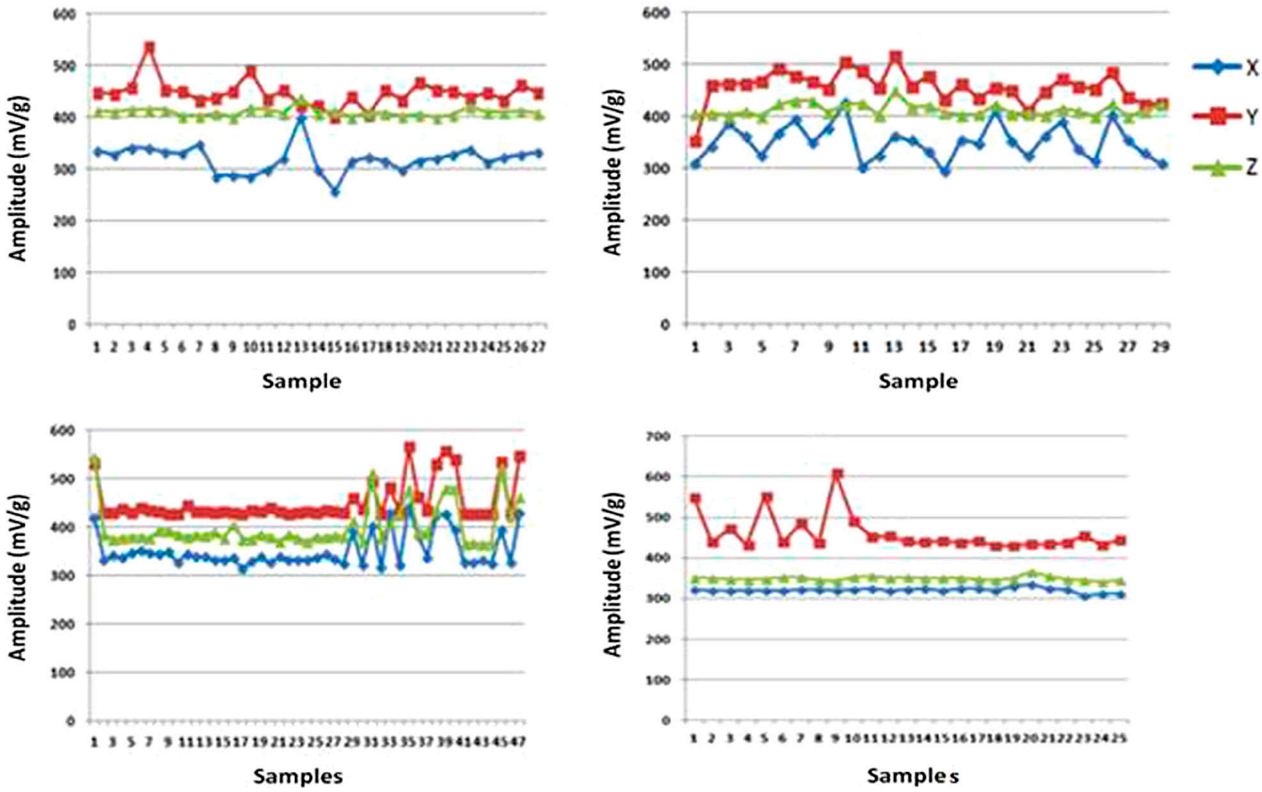

Figure 4: Plot of four bite datasets recorded.

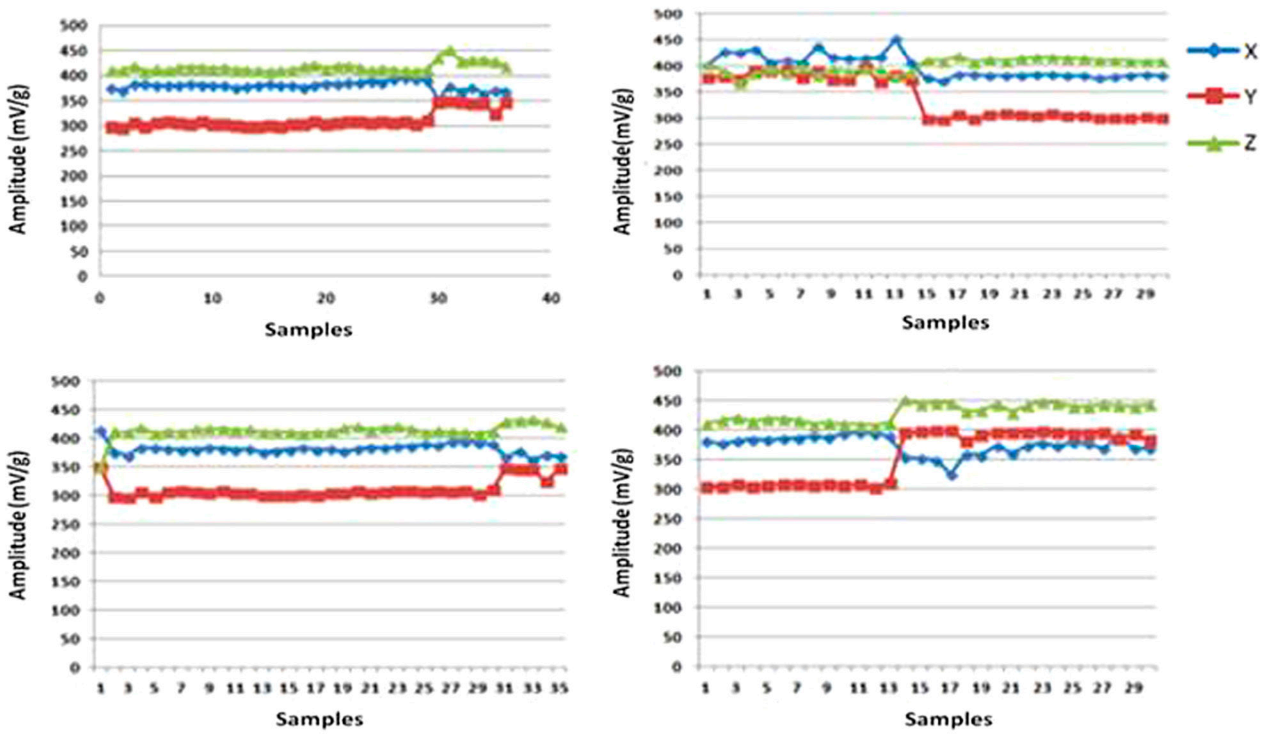

Figure 5: Plot of four chew datasets recorded.

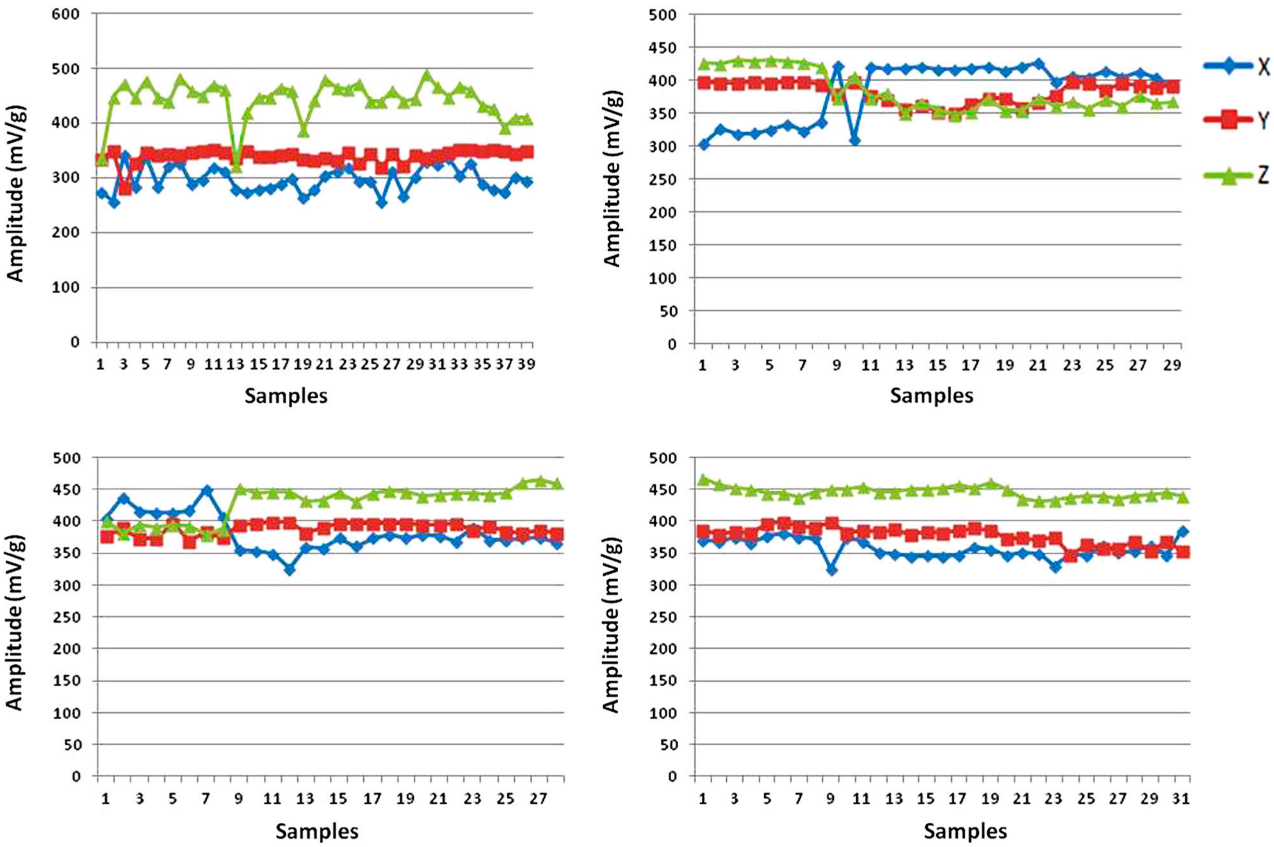

Figure 6: Plot of four chew–bite datasets recorded.

From Figure 7, it is evident that identification of bite, chew, and chew–bite events are possible from its combinations. Thus the bite, chew, and chew–bite event occurrence in the plot can be considered as the indication of good health in cattle.

Discussions

In the existing method, microphone has been used to record the sounds of chew, bite, and chew–bite of the cattle by attaching a microphone to the forehead of the cow. In this method, the microphone also records the sounds of other sources such as sounds from engines of machinery, sounds produced by nearby cows, etc along with the useful sound. This may lead to misclassification of chew, bite and chew-bite events for a particular cow. This further leads to many unwanted problems. Moreover, the signal produced by the microphone has to be conditioned, filtered, amplified, shifted and further processed for classification and the information cannot be obtained immediately (Deniz et al., 2017). The above addressed problems have been overcome in the proposed work by giving a sensor-based solution, which makes it suitable to be used in big farms as it differentiates grazing events such as chew, bite, and chew–bite accurately.

Conclusions

An electronic system capable of real-time monitoring of the feeding behaviour in ruminants was designed and implemented The motivation of this work was to provide a tool to enhance the understanding of feeding activities by developing embedded technology that allows for continuous monitoring of animal feeding activities under different environmental conditions. The electronic system was implemented using Arduino uno, accelerometer sensor, Wi-Fi module with power management technology combined with a high efficiency harvesting power supply and power management firmware.

This system is developed using low cost, low power consumption wireless sensor for cattle monitoring. Result shows that this system monitors the feeding activities of animals effectively. The animal monitoring system can also be applied to other animals such as sheep and goat.

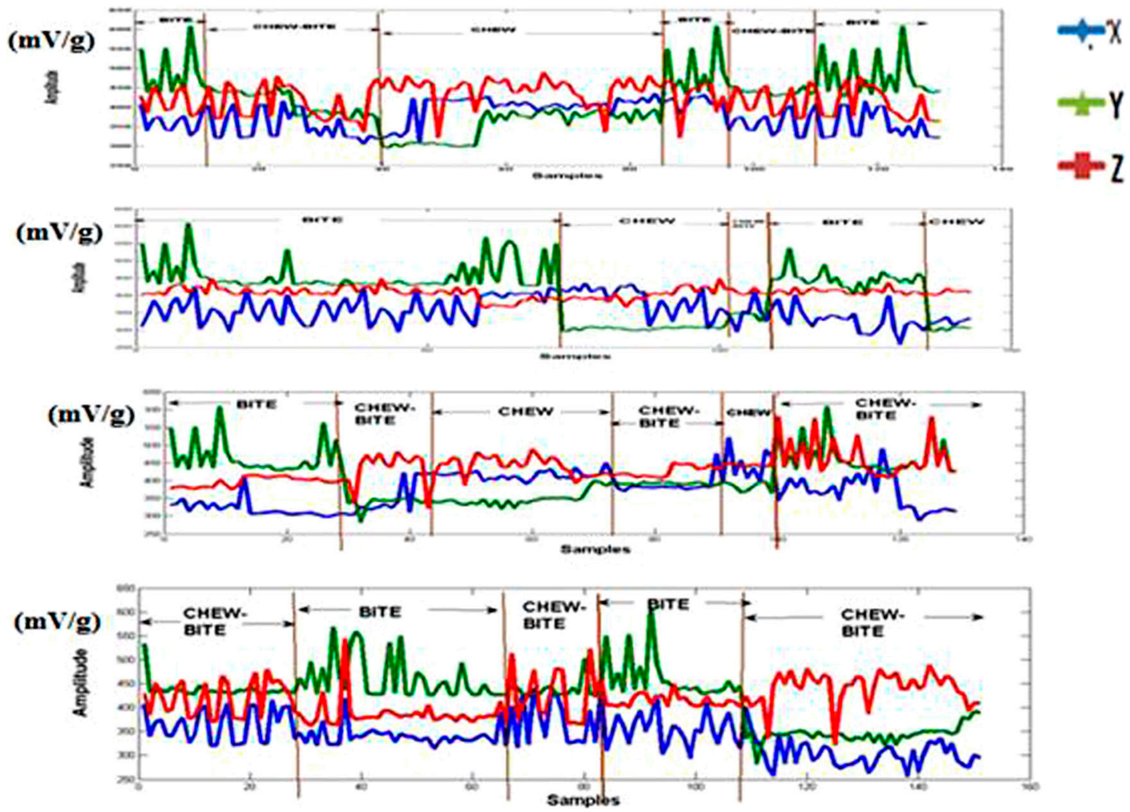

Figure 7: Plot which shows the combination of bite, chew, and chew–bite events.

In the existing method, the chew event was better recognized than the other events (Deniz et al., 2017). In the proposed method, all the three events were better recognized. The reason was that the accelerometer sensor employed in the proposed work was able to capture even a very minute jaw movement of the cattle. The device was placed on 30 cows and real-time datasets were taken. Thirty datasets were recorded during bite event, 35 datasets were recorded during chew event in which 26 datasets indicated chew event and 14 datasets indicated chew-bite event. Hence, 65 datasets were taken totally from 30 cows.

The bite, chew, and chew–bite values of cattle can be received in the mobile/system of the cattle owner. Based on the bite, chew, and chew–bite of the cattle, it can be diagnosed, whether the cattle is healthy or not. The bite, chew, and chew–bite of the cattle are directly related to its health. Healthy cattle should have a good means of bite, chew, and chew–bite. The device has been sealed and packed in a proper manner, so as to avoid any kind of disturbance to the cattle and also make it convenient to be used by cattle owners. The embedded device introduced in this work has the advantages of easier mounting on the animal, lack of complex wiring between the sensor and device and also low weight.

As a future work, GPS can be employed instead of Wi-Fi module to overcome the power instability issue. In the present work, an additional memory is included to overcome the power instability issue. Moreover, nano sensor can be employed to make the system more compact and a solar panel can be used to charge the batteries under field conditions. The above modifications can be incorporated to make the proposed set-up more efficient and robust.

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