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IoT ENABLED PRECISION LIVESTOCK FARMING AND FOCAL BEHAVIOR OF SHEEP USING TRI-AXIAL ACCELEROMETER SENSOR

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Abstract -

Exertion monitoring activity and focal behavior of animals that leads to identify individual health and well being support of precision livestock farming. The purpose of this research is to determine the diel activity of sheep on pasture using triaxial accelerometer sensor. The sensor is placed in the neck collar and ear tags mounting a triaxial accelerometer and were monitored during targeted periods of sheep activities: Standing, Lying ,Grass feeding , Walking and resting. The corresponding acceleration facts were fitted based on the classification. This classification was then applied to accelerometer data from an additional 25 ewe lambs to decide their activity. Each of these was fitted with a neck collar mounting an accelerometer as well as two kinds of accelerometers were placed on a head halter and a body harness over the shoulders of the sheep. These were monitored continuously for one week. The accuracy rate of classification is 91.4% was achieved for the basic six sets of activities like Standing, Lying, Grass feeding , Walking ,Resting and Abnormal activity in sheep. Triaxial accelerometer data will analyze the focal behavior based on the sheep activity. Similar activity data were achieved only from the halter mounted sensors, but not from the body harness. The results are consistent with existing studies directly observing daily activity of pasture-based sheep and to predict animal health and to reduce sheep mortality and increase production efficiency.

Keywords: Sheep; Diel activity; Classification algorithm; Tri-axial accelerometers; Health Prediction

1. Introduction

Precision Livestock Farming (PLF) is defined as individual management by continuous real-time monitoring of health, welfare, production/reproduction, and environmental impact. Precision Livestock Farming is playing a major role in the fourth industrial revolution , also known as Industry 4.0. PLF helps the farmers to enhance their decision management by tracking enormous animals and detecting small but significant changes in behavioral patterns or unrelated parameters through automated monitoring devices like sensor cameras, microphones, Internet access, and wireless communication networks, as well as other computer software programs. In addition to enhancing farm profitability, efficiency, and sustainability by improving livestock management, PLF also aims to create a perfect synergy with livestock farming.

Sheep are a prey species, and their only defense is to flee. Sheep display an intensely gregarious social instinct that allows them to bond closely to other sheep and preferentially to related flock members. Flock mentality movements protect individuals from predators. Flocks include multiple females, offspring, and one or more males. Ewes tend to stay in their maternal groups for life, whereas rams may form transient, unstable, and easily disbanded bachelor herds. If most rams in a group die because of fights or diseases, those remaining join another group. Under standard grazing situations, sheep graze together in casual affiliations; social hierarchies are not as apparent . Monitoring the exertion of animals using smart technologies such as accelerometer sensors can give an indication of an individual response to its external or internal surroundings . These technologies are extensively used in wildlife ecology studies and in an adding number of animal studies to infer the behavioral responses of animals to their surroundings.Triaxial accelerometers provide simultaneous measurements in three orthogonal directions, for analysis of all of the vibrations being experienced by a structure. Each unit incorporates three separate sensing elements that are oriented at right angles with respect to each other. In domestic sheep, the accelerometer data has been used to develop classifier algorithms to identify different focal behavior of several types of sheeps . The focal behavior of sheep include Grass Feeding , Lying, Standing, Walking, and Resting. Wearable sensor technologies show promise over traditional animal behavior measurements due to the possibility of managing individual animals without any physical involvement. If low cost and scalable, these technologies can also be easily upscaled to the monitoring of large sheeps.

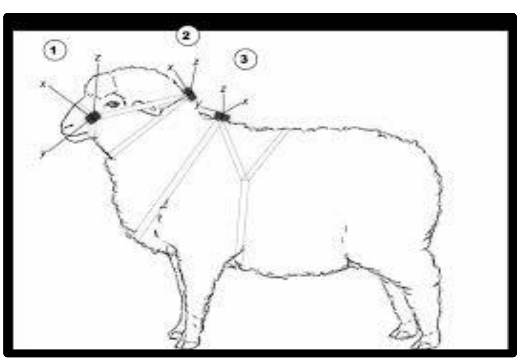

Figure 1 : Sensor Monitoring in Sheep

2. IoT Enabled Precision Livestock Monitoring:

Precision Livestock management, moreover called farm animals tracking, or precision farming, IoT-enabled devices are used to show livestock, generally farm animals. Traditional strategies of farm animals monitoring incorporate individually analyzing animals for signs and signs of disorder or harm. IoT-enabled farm animals manipulate the guesswork out of sheep health. The use of a wearable collar or tag, battery-powered sensors show the location, temperature, of animals and wirelessly the data in near-actual-time to farmers' devices. IoT solutions and clever gadgets are making large adjustments in sectors like farming and cattle. While everything is hooked up round us thru the internet, it's almost now not viable for us to anticipate lifestyles without the internet of factors.

The Internet of Things enabled Livestock monitoring platform is a boon for animal farming. IoT- enabled livestock control records offer results on different factors of animal health. Using a wearable collar, prepared with detectors, monitoring of the position, temperature, blood pressure, and coronary heart charge of creatures may be done. These wearable IoT widgets wirelessly transport the records of each beast at the ranch to a significant unit, known as IoT Gateway.The tracker tool is made small in size and mild weighted in order that creatures do n't discover big over their body. The GPS tracker and detectors are included into the tool in order that the animal moves and fitness may be covered 24x7. The behavioral monitoring function of the device can help the growers to honor what their cattle are eating.There are cellular programs and internet apps or IoT Dashboards related to the tackle. With the backing of the software related to the device, growers can produce digital obstacles with geofencing to steady the places wherein the cattle can pass freely.The tracker sends indicators to the cellular software if the cattle moves past described obstacles. It also sends pointers if the cattle are consuming or ingesting toxic. This way, the growers can store their cattle from health issues. The machine can work on LPWAN, which goes far and wide, as a result making sure the right connections. There are different LPWAN protocols which are decided in step with the operation.

3. Materials and Methods:

The use of Tri-axial Accelerometer Sensor and the focal behavior of sheep activity is analyzed from the data collected from the sensors , finally experimental classification is calculated by test model performance for different body locations of the accelerometers in identifying the diurnal activity of sheep, with the collar as the reference.

3.1 Tri axial Accelerometer Sensor

Sheep were fitted with ActiGraph wGT3X-BT® accelerometers (ActiGraph, LLC, Pensacola, FL, USA), which weighed 19 g and were 46 × 33 × 15 mm in size. The wGT3X-BT® records accelerations from the individual's amplitude (g) and frequency (Hz) of movement across three axes (X for front-to-back; Y for side-to-side; and Z for up-down) as mentioned in Figure 2, and was attached onto the top side of a neck collar with a cable tie, and in two additional monitors were used. One was fastened to a head halter adjacent to the cheek and the second on a ram mating harness being positioned over the shoulders .

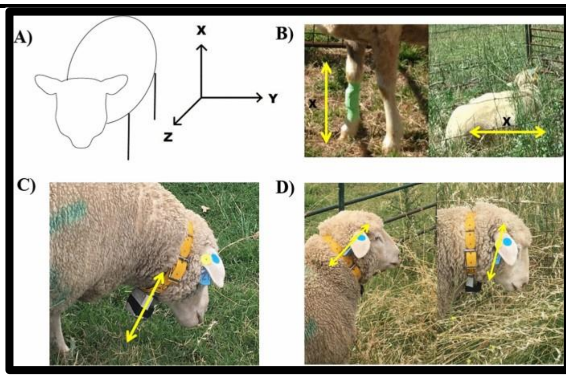

Figure : 2 Tri axial Accelerometer

The tri axial accelerometers were pre-scheduled to sample data at a rate of 30 Hz, i.e., 30 data points per second. For comparison in phase 2, the tri axial accelerometers on the shoulders of sheep had the front-to-back orientation on the Y axis, side-to-side movement on the X axis and up-down on the Z axis, with these body axes 90° different to those on the neck collar of the sheep . For the head halter the tri axial accelerometers had employed front-to-back movements on the X axis, side-to-side on the Z axis, and up-down on the Y axis. This difference in orientation was corrected and accounted for prior to analysis.

3.2 Focal Behaviour of Sheep Activity

Five categories of behavioral activities were defined a priori based on previous work in order to compare behavioral categories collected from accelerometry against behavioral observations. These categories included:

1. Grass feeding - head down while standing still or slowly moving forward whilst ingesting grass with the muzzle close to the ground.
2. Standing - standing with head up greater than 5s, with low head movement.
3. Walking - head up whilst walking at a slow pace/running at a fast pace. Head raised at or above horizontal plain scanning indicates the eyes open in sheep.
4. Lying - lying down with minimal head movement.
5. Resting - lying or sleeping without head movement .
6. Abnormality - due to discomfort and pain that expressed in face of ewes

Table 1 : Focal Behaviour of Sheep Activity

Activity	Posture	Animal	Description
Grass Feeding	Standing/Sitting	Ewes	Animals grazing with their head down - can be stationary or moving ≤ 3 consecutive steps (ranging).
Walking	Standing	Ewes	Animals purposely travel with > 3 consecutive steps - head may be up or level.
Standing	Standing	Ewes/ Sheep	Animals' stationary with minimal head movements - head may be up or level.
Lying	Lying	Sheep	lying or sleeping without head movement
Resting	Lying	Ewes/ Lambs	Animals ruminating with their heads up.
Abnormal Activity	Facial Expression Scale	Ewes/ Lambs	Reliably measure pain and discomfort in sheep

3.3 Experimental Classification:

Three experimental tests were conducted based on the sheep focal behavior like grass feeding, standing, lying, walking and resting. All the sheeps were filmed during these experimental tests. Video recordings were made using a Canon NX300 digital camera. All observations were conducted during morning and evening time. The starting times for the ten observation sessions per day are shown in Table 2. Video observations were taken from a 200 meter to 300 meter distance using the camera's zoom lens in order to avoid disruption of the sheep. Experiment tests were designed to capture grazing activity, all other activities were also captured during this time. Lying activity was opportunistically targeted during the late morning period. Thus based on the focal behavior of sheep / ewe lambs the health prediction and signs of an unhealthy animal include isolation from the rest of the herd/flock, abnormal eating habits, depression, scouring or diarrhea, abnormal vocalization, teeth grinding, or any other abnormal behavior can be prevented and thus improving in production and raising healthy precision livestock farming

Table 2 : Starting time and duration of focal behavior observation sessions recorded by video across three experimental periods on ewe lambs (*n* = number of sheeps) fitted with a collar mounting an Actigraph® wGT3X-BT accelerometer sensor.

Date	Focal Behaviour	Start	End	Duration (mins)
02/02/2023	Grass Feeding	2:41:05 PM	2:51:00 PM	10:05
02/02/2023	Lying	4:15:00 PM	4:45:00 PM	30:00
03/02/2023	Standing	10:46:50 AM	11:16:35 AM	29:59
03/02/2023	Standing	11:17:15 AM	11:22:15 AM	5:09
03/02/2023	Walking	11:28:00 AM	11:44:55 AM	17:03
05/02/2023	Grass Feeding	1:17:35 PM	1:47:25 PM	29:59
05/02/2023	Grass Feeding	1:48:40 PM	2:18:30 PM	29:59
06/02/2023	Walking	2:19:10 PM	2:34:10 PM	15:40
07/02/2023	Resting	3:19:10 PM	3:34:10 PM	15:40
07/02/2023	Abnormality	4:40:10 PM	5:30:10 PM	50:00

Using the behaviors , all videos were watched and coded by the same person who monitors the focal behavior of sheep.. An activity profile of each sheep was created from videos by annotating and coding activity type at five seconds interval (i.e., five seconds epochs) using CowLog®, an open-source software for coding behaviors from digital video

4. Collection of Accelerometer Data from Different Body Locations

The sensor data from each body location were collated for a 72-h period commencing at 0900 h on the day of attachment of the sensors to the sheeps , and presented as three daily blocks, that is throughout the day . As mentioned below, the orientation of the X, Y and Z axes differed between the attachment methods. This was adjusted prior to analysis. Then the classification model was applied to deduce activity at each interval..

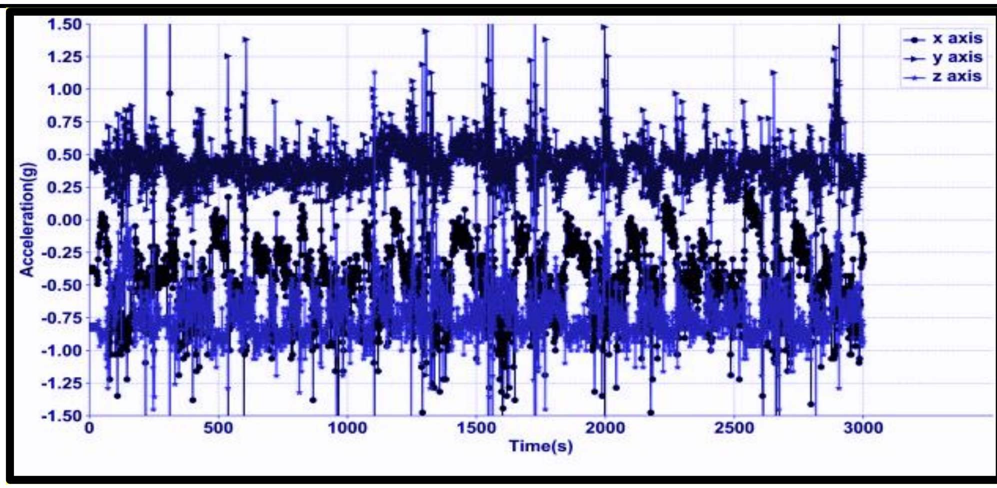

Figure 3.1 : The acceleration waveforms in grass feeding behavior

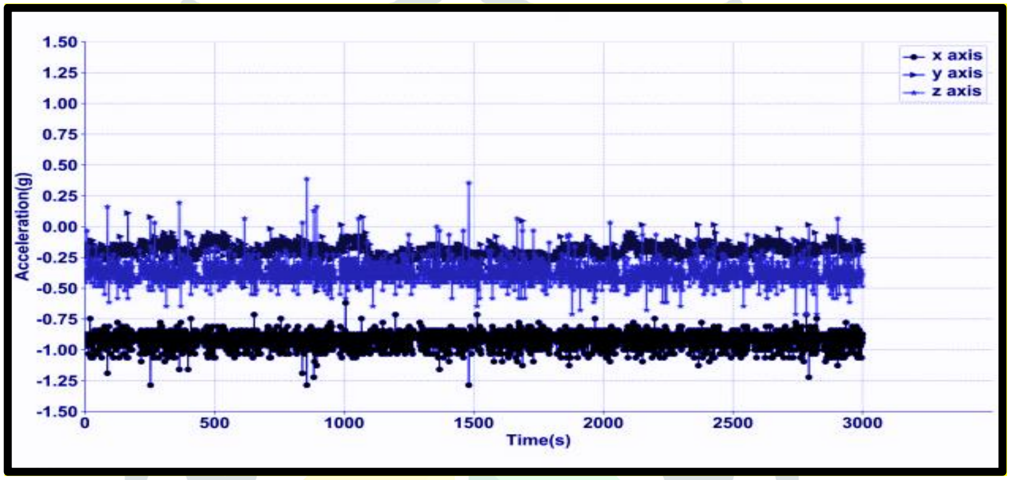

Figure 3.2 : The acceleration waveforms in walking behavior

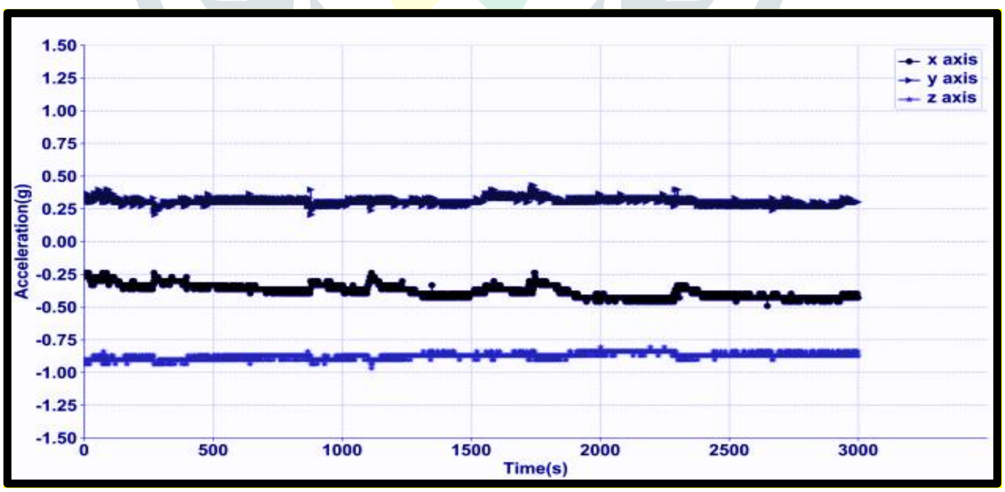

Figure 3.3 : The acceleration waveforms in Resting behavior

We then separately compared the focal behavior of sheep for the head halter and the harness to the sensor of the collar. Four performance metrics were calculated as outlined in Equations,

Sensitivity=TP/(TP+FN)

Specificity=TN/(TN+FN)

Precision=TP/(TP+FP)

Accuracy=(TP+TN)/(TP+TN+FP+FN)

where, TP (true positive) corresponds to the number of epochs where the behavior of interest was correctly predicted by the classifier. TN (true negative) is the number of epochs where the behavior of interest was correctly classified as not having occurred. FN (false negative) is the number of epochs where the behavior of interest was observed but not inferred by the classifier. FP (false positive) is the number of epochs where the behavior of interest was inferred by the classifier but not observed.

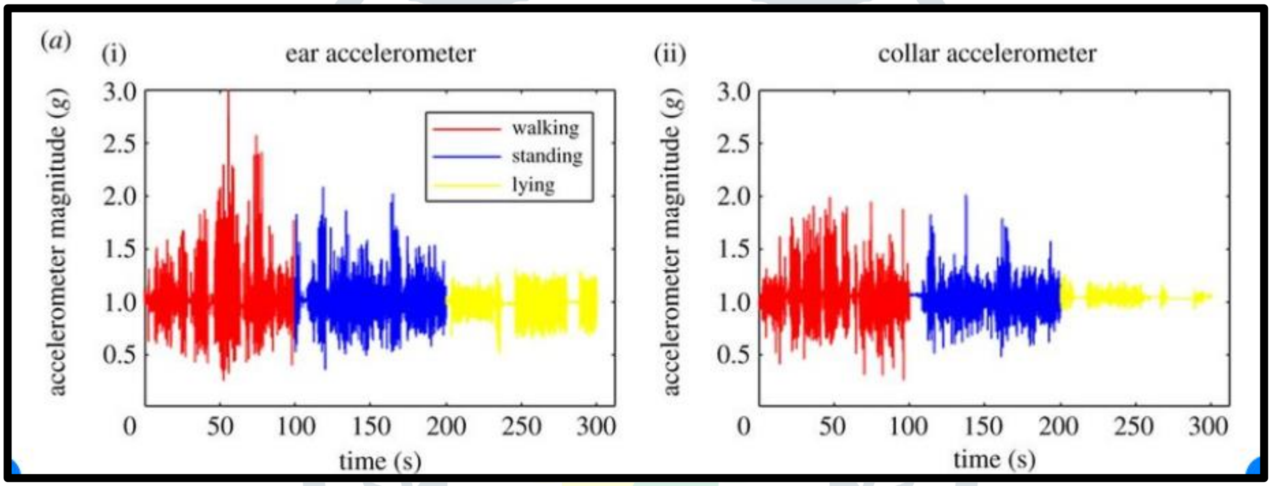

Figure 4.a : Data collected in collar and ear mounted sensors using Tri Axial Accelerometer i) ear accelerometer ii) collar accelerometer

4. CONCLUSION

This paper demonstrates the value of raw, untransformed accelerometry data to presage discrete numerical signatures associated with grass feeding , resting and walking and other behavior of sheep. The change in focal behavior of sheep monitored from morning and evening are derived from sensor data, similar to those reported in other studies using direct observation, showing that sheep spend most of their daytime grazing. These experimental results confirm that tri-axial accelerometer sensors can be a very effective tool for identifying the focal behavior of sheep. This results in finding the basic behavioral activity of sheep, and future research for identifying all time activity in sheep on pasture in response to changing internal and external environmental conditions. Overall, the technology shows promise to inform early identification of deviations in normal diel activity of sheep and provide the better results of using these in farming with decision support towards better health and welfare outcomes and enhancing farm profitability, efficiency, and sustainability by improving precision livestock farming.

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