AJMS
Asian Journal of Mathematical Sciences

RESEARCH ARTICLE

Framework for Modeling Cattle Behavior through Grazing Patterns

Rotimi-Williams Bello[1], S. Abubakar[2]

[1]Department of Mathematical Sciences, Faculty of Basic and Applied Sciences, University of Africa, Toru-Orua, Bayelsa State, Nigeria, [2]Department of Mathematics, School of Science Education, Federal College of Education (Technical), Bichi, Kano State, Nigeria

Received: 31-12-2019; Revised: 27-01-2020; Accepted: 10-02-2020

ABSTRACT

Monitoring cattle behavior in the grazing field has been a perpetual challenge in animal husbandry and for nomadic herdsmen. Various methods have been used in the past to monitor the behavior of cattle and their grazing patterns. Most of the grazing patterns in the nomadic system demand that both the herdsmen and their cattle cover some distance from dawn to dusk searching for greener pasture, this, and unavailability of the greener pasture sometimes result to tiredness and exhaustion which in turn trigger the change in behavior exhibited by the cattle. The economic implication of such a change in the cattle behavior might be catastrophic if not given the necessary attention. Presented in this paper is a framework for modeling the behavior of cattle grazing patterns including monitoring of their movement and the distribution of grazing events in the paddock. The correlation between the pasture condition and the grazing behavior of cattle in the paddock was analyzed. Global positioning system (GPS) monitoring collar for cattle was used to monitor the behavior and to detect the change in grazing patterns of the cattle.

Key words: Cattle behavior, grazing field, grazing patterns, modeling, global positioning system

INTRODUCTION

In Kilgour (2012), cattle can exhibit up to 40 individual behaviors, though many of these are expressed in low abundance and for very short time periods. Three main behaviors (grazing, resting, and walking) were identified but one (grazing) was used in this work. Reported in Hancock (1954) was that the main behaviors of pasture-based cattle were grazing and resting. In Homburger *et al*. (2014), there was a reported difficulty by others using GPS data in differentiating between when cattle are lying and when they are standing. Whenever cattle's head was bent down plucking at the pasture, whether lying, walking, or standing still, grazing was said to take place. Whenever the cattle take the posture of lying or standing with the head raised, it means that such cattle are resting. Cattle selected had normal gait (Whay *et al*., 2003) and showed no other obvious signs of ill health. Cattle were randomly selected for behavioral observation over the study period and observed between the hours of 09:00 and 17:00 so as to get the longest period of observation during grazing.[1-10]

Cattle that are cultured free from diseases, being properly fed, and having normal physical functions make up a healthy population. Hence, keeping the strong cattle stronger and the healthy ones healthier for the overall economic benefit and peaceful coexistence of the herdsmen and their cattle with their grazing environment are the critical concerns for cattle husbandry business. Devising the techniques to monitor the activities of out of sight cattle in a grazing field has been a perpetual challenge in animal husbandry and agricultural practice. Various methods have been used in the past to monitor the conditions that can constitute a change in cattle behavior (Bello, 2018), apart from the conditions that can be linked to health challenges, the conditions range from how greener the pasture is, to how accessible to the cattle the greener pasture. In this proposed

Address for correspondence:
Rotimi-Williams Bello,
E-mail: sirbrw@yahoo.com

framework, the relationship between the pasture condition and the behavior of cattle in the grazing field is analyzed.

GPS monitoring collar for cattle was placed on cattle's neck to monitor the behavior of the cattle [Figure 1]. The GPS monitoring collar allows the out of sight monitoring of the cattle activities during grazing activities. The GPS gives feedback analysis of the grazing activities of the cattle, especially when such cattle have deviated from the normal route or have fallen to unfavorable atmospheric conditions resulting in behavioral change. This method of monitoring cattle activities in the grazing field possesses a lot of advantages compared to the traditional method where herds of cattle would be manually monitored by one or two herdsmen, thereby resulting into late awareness to the herdsmen all that happen to the cattle that are out of sight. The technology behind GPS has enabled herdsmen to be in control of their cattle in the grazing field even when they are out of range.

In summary, we set the following as the paper objectives (1) to design a framework for modeling the behavior of cattle through cattle grazing pattern and (2) to provide alert signals of any health challenge and boundaries violation by the cattle during grazing using GPS monitoring collar. The outcome of this research could profoundly reshape our relationships with domesticated animals, the landscape, and each other.[11-15]

THE STUDY OF CATTLE BEHAVIOR AND CATTLE GRAZING PATTERNS

Hence, many literary works have been carried out that attributed change in cattle behavior to the change in their health status. For example,

Figure 1: Cattle equipped with a collar-mounted GPS device (digitanimal.com)

Huzzey *et al*. (2007) in Williams *et al*. (2016) used electronic feed bins to record feeding behavior in housed dairy cows. They discovered that feed intake and time spent feeding began to decrease 2 weeks to clinical diagnosis of severe metritis. González *et al*. (2008) found that daily feeding time, number of visits to the feed bin, and feeding rate began to decrease as early as 30 days before lameness diagnosis in housed cows fed a silage ration. With larger herds and limited time, disease diagnosis becomes more difficult. Mobility scoring is one example of a subjective technique used by herdsmen to identify lameness and locomotors problems in dairy cows (Williams *et al*., 2016). Although cheap to disseminate, mobility scoring is time consuming and must be done regularly (Pluk *et al*., 2012) (Van Nuffel *et al*., 2015). Another criticism of the technique is that it may fail to identify the early (subclinical) stages of lameness.

Reported in Reader *et al*. (2011) was that the milk yield of cows decreased by an average of 0.7 kg/d for approximately 7 weeks before cows became visually lame. Moreover, after recovery, the milk yield of lame cows remained lower for 4 weeks. Identifying production disease as early as possible is, therefore, imperative to minimize welfare implications and production loss. In Williams *et al*. (2016), a technology designed to identify lame cows using pressure plates to measure weight distribution, for example, has already been assessed (Bicalho *et al*., 2007). Although they concluded that more work was needed to refine the sensitivity of these devices, weight shifting by the cow may be visible by gait assessment, and therefore, these tools are likely to be effective in reducing the labor cost of mobility scoring. An approach to identify subclinical disease possibly using behavioral changes before gait abnormalities are present may be more constructive.[16-19]

When cattle in motion are moving sluggishly with serious complexity, to differentiate, the status of their behavior is a great task. Sometimes, cattle irrationally and frequently change in behavior within a short period of time without any justification making it difficult to differentiate them. Behavioral classification of grazing cattle from position data has been worked on with different approaches by several authors. In Anderson *et al*. (2012), beef cows were tracked at time intervals of 1 s and threshold values of mean movement rate calculated for 1 min periods were

used to distinguish between grazing, resting, and walking. To get a reliable result for behavioral classification, several factors must be involved. The first determining factor is the factor that measures the exactness of the distant tracking device (Witte and Wilson, 2005) (Patterson *et al*., 2010). The second determining factor as opined by Bailey *et al*., 2006 is the role that can be played by behavioral variation between breeds of the same species including different animal species in the determination of distinct behavioral states. The third factor is the influence that the time interval between GPS measurements in the field can have over classification accuracy (Postlethwaite and Dennis, 2013).

And finally, the statistical approach used for the classification may determine the outcome. State-space models often used for process modeling of quantitative studies that have to do with the behavioral classification of bio-logging data (Patterson *et al*., 2008) or linear discriminate analysis (Schlecht *et al*., 2004) and machine learning such as classification trees (Shamoun-Baranes *et al*., 2012). Data points are grouped by machine learning methods based on some similarity measurement. Machine learning methods though, easy to implement and flexible, ignore the temporal and spatial process which underlies the data; while the underlying process was retraced by state-space models through explicitly modeling of data in the temporal and spatial order, in which they have been recorded. Although additional sources of errors were able to be integrated (Patterson *et al*., 2008), more efforts are required for implementation and higher computational power.

As earlier iterated, the aim of the study is to model the behavior exhibited by the cattle when changes occur in the surrounding environment during grazing. Factors that contribute to a negative effect on cattle behavior are known as agents. In this study, the focus is primarily on physical agent and secondarily on the chemical agent. The most common physical agent that affects cattle is the temperature. Any drastic change in temperature, for example, will seriously affect cattle behavior.

METHODOLOGY OF THE FRAMEWORK

This study observes the grazing patterns of cattle and their behaviors in the grazing field. To accomplish the above observation, GPS monitoring collar for cattle is utilized [Figure 1]; this technology monitors the process and activities of cattle during grazing through a networked system [Figure 2]. The requirements of this study are to analyze the movement and grazing patterns of cattle and GPS tracking processing. Tracking cattle movement in a free range during grazing is difficult; among the various monitoring and tracking algorithms currently available, the most suitable algorithm to use is the GPS algorithm which provides the ability to track the object that is moving in a disordered environment. This algorithm allows the capability of monitoring the cattle in a somewhat disordered environment as the cattle are in free range.

The observation of the pasture quality is also a crucial part of this study as drastic changes in the chemical condition of the pasture can seriously affect the health of the cattle. Changes in several pasture conditions such as nutrient content can cause the cattle to be in a stressful state which might most probably lead to (1) cattle intruding the prohibited area, (2) disease, and (3) death. A normal and healthy cattle will behave active, maintain normal body color, and engage in a social (schooling) activity. Stressful factors, whether physical or chemical, make the cattle to be in a state of stress. When these cattle are in such a state, they manifest this through their behavior and

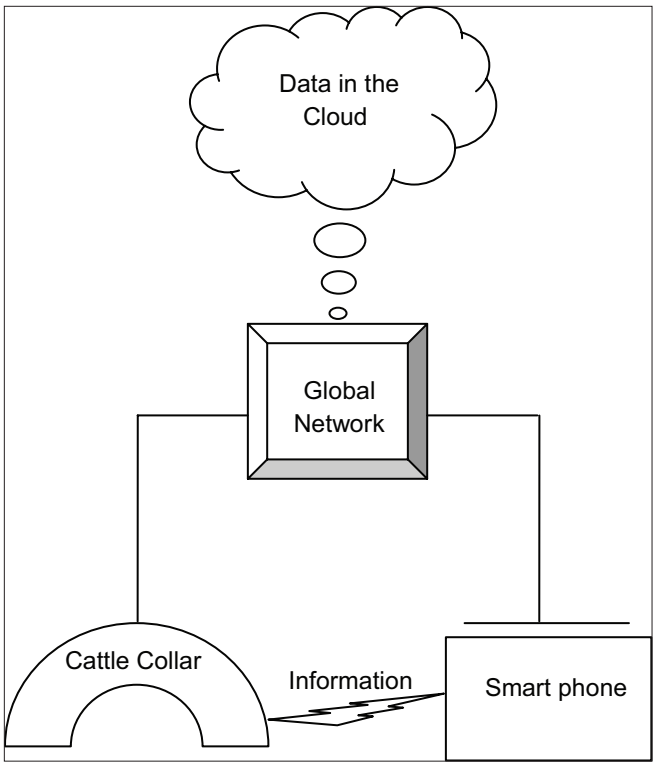

Figure 2: Framework overview

the easiest way to observe this is in the way they graze or their grazing patterns. For example, a sign of fatigue emerges when the cattle show reduced activity and movement than normal and a distinct change in feeding than usual. They will break apart from social activity and start grazing individually. Exhaustion shows when the cattle are alienated, commonly lying in the grazing field both at dusk and at dawn, showing minimal or almost no response to the environment. Since the cattle exhibit changes in their grazing patterns and behavior, the GPS will be able to record this and with the application of the suitable algorithm, we are able to model out the behavior of the cattle based solely on its grazing patterns. The GPS monitoring collar is connected to the network through cloud technology. GPS monitoring collar is placed on the neck of the cattle. As it is positioned round the cattle's neck, a view of the whole paddock enables the grazing patterns and behavior of the cattle to be monitored. This GPS monitoring collar directly connected to a network provides continuous real-time monitoring of the grazing. The real-time monitoring of cattle and grazing patterns is constantly monitored and analyzed to detect any abnormalities or stress sign that the cattle may exhibit. The pasture quality and deviation of cattle from boundaries in the grazing field are also being monitored.[20-24]

In achieving this, we made use of multiple sensors which are only sensitive toward a specific agent. These sensors are (1) temperature sensor that records temperature per GPS location fix. The sensor is not directly exposed and may display lag time in response to rapid temperature changes; (2) dual-axis motion sensors that record animal movement and are sensitive to horizontal and vertical movements of the head and neck. As these sensors read the condition of the environment, the data are sent continuously to the server, thus providing real-time monitoring. The server analyzes the data received for any abnormal or irrelevant value. The analysis of the data received by the server is handled by a custom-developed application (TR20). Given the linear flow of the process, a simple feedforward neural network is implemented. The data flow directly through as inputs and produced an output if a particular condition is met. Any changes with the behavior and grazing patterns of the cattle in the grazing field, especially going beyond boundaries, will cause the application to trigger an appropriate alert.

CONCLUSION

This paper has presented a framework for the modeling of cattle behavior through the monitoring of cattle grazing patterns. The behavioral change exhibited by cattle during grazing was a reflection of so many happenings during grazing. These behavioral changes exhibited by cattle were monitored in the past using different approaches, but this paper considered the use of GPS monitoring collar that uses a network that is cloud based for the recording of events data. The usage of GPS as monitoring technology leads to efficiency. The movement of the cattle in the grazing field generates a function approximation graph to identify the factors reacting to the cattle.

As there are different species of animal, so also there are different behaviors exhibited by these animals. The behavior of livestock, wild animals, and domestic animals is not the same. Moreover, the taxonomy of animal does not guarantee the same behavior from them. This is a challenge for monitoring the behavioral changes exhibited by these animals. Animal tracking and monitoring technology have progressed dramatically in the past few years. An interesting thing worthy of emphasizing in the course of this article is that, with the application of GPS, one can encompass a vegetation situation, change the behavior of the very stubborn cattle, virtually monitoring cattle to restrict their movement.

This work is just a hypothetical description of a complex entity involved in the modeling of cattle behavior through cattle grazing patterns. Further research is required for the development and investigation of the effect of the hypothetical framework in controlled field experiments.

REFERENCES

1. Anderson DM, Winters C, Estell RE, Fredrickson EL, Doniec M, Detweiler C, Nolen B. Characterising the spatial and temporal activities of free-ranging cows from GPS data. Rangel J 2012;34:149-61.
2. Bailey DW, VanWagoner HC, Weinmeister R. Individual animal selection has the potential to improve uniformity of grazing on foothill rangeland. Rangel Ecol Manag 2006;59:351-8.
3. Bello RW. An overview of animal behavioral adaptive frightening system. Int J Math Phys Sci Res 2018;6:126-33.
4. Bicalho RC, Cheong SH, Cramer G, Guard CL. Association between a visual and an automated locomotion score in lactating Holstein cows. J Dairy Sci 2007;90:3294-300.

5. Dyer RM, Neerchal NK, Tasch U, Wu Y, Dyer P, Rajkondawar PG. Objective determination of claw pain and its relationship to limb locomotion score in dairy cattle. J Dairy Sci 2007;90:4592-602.
6. González LA, Tolkamp BJ, Coffey MP, Ferret A, Kyriazakis I. Changes in feeding behavior as possible indicators for the automatic monitoring of health disorders in dairy cows. J Dairy Sci 2008;91:1017-28.
7. Hancock J. Studies of grazing behaviour in relation to grassland management I. J Agric Sci 1954;44:420-33.
8. Hickman CG. Cattle Genetic Resources. Philadelphia, PA, St. Louis: Elsevier Science Publishers; 1991.
9. Homburger H, Schneider MK, Hilfiker S, Lüscher A. Inferring behavioral states of grazing livestock from high-frequency position data alone. PLoS One 2014;9:e114522.
10. Huzzey JM, Veira DM, Weary DM, von Keyserlingk MA. Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. J Dairy Sci 2007;90:3220-33.
11. Kilgour RJ. In pursuit of "normal": A review of the behaviour of cattle at pasture. Appl Anim Behav Sci 2012;138:1-11.
12. Manske T, Hultgren J, Bergsten C. Prevalence and interrelationships of hoof lesions and lameness in Swedish dairy cows. Prev Vet Med 2002;54:247-63.
13. Patterson TA, McConnell BJ, Fedak MA, Bravington MV, Hindell MA. Using GPS data to evaluate the accuracy of state-space methods for correction of Argos satellite telemetry error. Ecology 2010;91:273-85.
14. Patterson TA, Thomas L, Wilcox C, Ovaskainen O, Matthiopoulos J. State-space models of individual animal movement. Trends Ecol Evol 2008;23:87-94.
15. Pluk A, Bahr C, Poursaberi A, Maertens W, van Nuffel A, Berckmans D. Automatic measurement of touch and release angles of the fetlock joint for lameness detection in dairy cattle using vision techniques. J Dairy Sci 2012;95:1738-48.
16. Postlethwaite CM, Dennis TE. Effects of temporal resolution on an inferential model of animal movement. PLoS One 2013;8:e57640.
17. Reader JD, Green MJ, Kaler J, Mason SA, Green LE. Effect of mobility score on milk yield and activity in dairy cattle. J Dairy Sci 2011;94:5045-52.
18. Schlecht E, Hülsebusch C, Mahler F, Becker K. The use of differentially corrected global positioning system to monitor activities of cattle at pasture. Appl Anim Behav Sci 2004;85:185-202.
19. Shamoun-Baranes J, Bom R, van Loon EE, Ens BJ, Oosterbeek K, Bouten W. From sensor data to animal behaviour: An oystercatcher example. PLoS One 2012;7:e37997.
20. Van Nuffel A, Saeys W, Sonck B, Vangeyte J, Mertens KC, De Ketelaere B, et al. Variables of gait inconsistency outperform basic gait variables in detecting mildly lame cows. Livest Sci 2015;177:125-31.
21. Whay HR, Main DC, Green LE, Webster AJ. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records. Vet Rec 2003;153:197-202.
22. Williams ML, Mac Parthaláin N, Brewer P, James WP, Rose MT. A novel behavioral model of the pasture-based dairy cow from GPS data using data mining and machine learning techniques. J Dairy Sci 2016;99:2063-75.
23. Witte TH, Wilson AM. Accuracy of WAAS-enabled GPS for the determination of position and speed over ground. J Biomech 2005;38:1717-22.
24. Weyenberg S. Variables of gait inconsistency outperform basic gait variables in detecting mildly lame cows. Livest Sci 2015;177:125-131. Availble from: http://dx.doi.org/10.1016/j.livsci.2015.04.008.