A Framework for Real-time Cattle Monitoring using Multimedia Networks

Rotimi-Williams Bello, Abdullah Zawawi Hj Talib, Ahmad Sufril Azlan Bin Mohamed

Abstract*: *Monitoring cattle behaviour has been a perpetual challenge in animal husbandry and animal breeding. Various methods have been used in the past to monitor the behaviour of cattle and their grazing patterns. We proposed a framework for real time cattle monitoring using multimedia networks. The study observes the grazing patterns of cattle and their behaviours in the grazing field. In order to accomplish the above observation, global positioning system monitoring collar for cattle is utilized; this technology monitors the activities of individual cattle during grazing through a networked system. The materials used in carrying out the work include cattle, waterproof global positioning system tracking collars (TR20) for cattle, and supporting application software by Sigfox's global Internet of Things network. The paddock size was 121 by 174 m. Forage was predominantly agricultural plants. Cattle weighing up to 580 kg were used. The collared cattle were used to initiate all data collections. Latitude and longitude information of location was cumulatively stored in memory that is on-boarded and big enough for the fixing of position. Each fix record is comprised of corresponding estimation of height, date and time of global positioning system, precision value dilution, status of fix, temperature, including horizontal and vertical activity sensor counts in intervals that are fixed. Units of collar were well compacted, robust, and of about 1 kg in weight. Location fixes for over a day period were showed through testing to be accurate, at roughly 95% for eight minutes of time after correction of the difference. There was no bias of direction on the part of errors that have consistency with other studies' finding.

Keywords*: *Cattle, Collar, Behaviour, Network, GPS

I. INTRODUCTION

In Kilgour [1], cattle can exhibit up to forty individual behaviours, though many of these are expressed in low abundance and for very short time periods. Three main behaviours (grazing, resting, and walking) were identified but one (grazing) was used in this work. Reported in Hancock [2], was that, the main behaviours of pasture-based cattle were grazing and resting. In Homburger et al. [3], there was a reported difficulty by others using global positioning system (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 [4] and showed no other obvious signs of ill health. Cattle were randomly selected for behavioural observation over the study period and observed between the hours of nine in the morning and five in the evening so as to get the longest period of observation during grazing. Cattle that are cultured free from diseases, being properly fed, and having normal physical functions make up a healthy population. So, 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 behaviour [5], 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 framework, the relationship between the pasture condition and the behaviour of cattle in the grazing field is analysed.

GPS monitoring collar for cattle was placed on cattle's neck to monitor the behaviour of the cattle (Fig. 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 unfavourable atmospheric conditions resulting in behavioural 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 are manually monitored by one or two herdsmen thereby resulting into late awareness to the herdsmen all that happens 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.

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* Correspondence Author

Rotimi-Williams Bello*, School of Computer Sciences, Universiti Sains Malaysia, 11800, Pulau, Pinang, Malaysia

A. Z. H. Talib, School of Computer Sciences, Universiti Sains Malaysia, 11800, Pulau, Pinang, Malaysia

A. S. A. Mohamed, School of Computer Sciences, Universiti Sains Malaysia, 11800, Pulau, Pinang, Malaysia.

In summary, we set the following as the paper objectives (1) to design a framework for real time cattle monitoring using multimedia networks (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, improves cattle traceability, cattle health information, cattle performance monitoring, mitigate rustling and cattle swapping.

II. RELATED WORKS

So many literary works have been carried out that attributed change in cattle behaviour to the change in their health status. For example, Huzzey et al. [6] in Williams et al. [7] used electronic feed bins to record feeding behaviour in housed dairy cows. They discovered that feed intake and time spent feeding began to decrease two weeks to clinical diagnosis of severe metritis. González et al. [8] found that the time for daily feeding, number of visits to the feed bin, and feeding rate began to decrease as early as thirty 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 [7]. Although cheap to disseminate, mobility scoring is time-consuming and must be done regularly [9-10]. Another criticism of the technique is that it may fail to identify the early (sub-clinical) stages of lameness [11-12].

Reported in Reader et al. [13] was that the milk yield of cows decreased by an average of 0.7 kg/d for approximately seven weeks before cows became visually lame. Moreover, after recovery, the milk yield of lame cows remained lower for four weeks. Identifying production disease as early as possible is therefore imperative to minimize welfare implications and production loss. In Williams et al. [7], a technology designed to identify lame cows using pressure plates to measure weight distribution, for example, has already been assessed [14]. 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 labour cost of mobility scoring [7]. An approach to identify sub-clinical disease possibly by using behavioural changes before gait abnormalities are present may be more constructive [7].

When cattle in motion are moving sluggishly with serious complexity, to differentiate the status of their behaviour is a great task. Sometimes, cattle irrationally and frequently change in behaviour within a short period of time without any justification making it difficult to differentiate them.

Classifying the behaviour of grazing cattle from position data has been worked on with different approaches by several authors. In Anderson et al. [15], it took one second time interval to track beef cows and threshold values of mean movement rate calculated for 1 minute periods were used to distinguish between grazing, resting and walking. To get a reliable result for behavioural classification, several factors must be involved. The first determining factor is the factor that measures the exactness of the distant tracking device [16-17]. The second determining factor as opined by [18] is the role that can be played by behavioural variation between breeds of the same species including different animal species in the determination of distinct behavioural states. The third factor is the influence that the time interval between GPS measurements in the field can have over classification accuracy [19].

And finally, the statistical approach used for the classification may determine the outcome. State-space models often used for process modelling of quantitative studies that have to do with the behavioural classification of bio-logging data [20] or linear discriminate analysis [21] and machine learning such as classification trees [22]. 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 modelling of data in the temporal and spatial order in which they have been recorded. Although, additional sources of errors were able to be integrated [20] but more efforts are required for implementation and higher computational power.

As earlier iterated, the aim of the study is to monitor cattle in real-time using multimedia networks. Factors that contribute to a negative effect on cattle behaviour 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 behaviour.

Fig. 1. Cattle equip ped with a collar-mounted GPS device

III. MATERIALS AND METHOD

This study observes the grazing patterns of cattle and their behaviours in the grazing field. In order to accomplish the above observation, GPS monitoring collar for cattle is utilized (Fig. 1); this technology monitors the activities of individual cattle during grazing through a networked system (Fig. 2).

The materials used in carrying out this work include cattle, waterproof GPS tracking collars (TR20) for cattle, and supporting application software by Sigfox's global Internet of Things (IoT) network.

The paddock size was 121 by 174 m. Forage was predominantly agricultural plants. Cattle weighing up to 580 kg were used. All data collections were initiated with the collared cattle. Latitude and longitude information of location was cumulatively stored in memory that is on-boarded and big enough for position fixes. Each fix

record is comprised of corresponding estimation of height, date and time of GPS, precision value dilution, status of fix, temperature, including horizontal and vertical activity sensor counts in intervals that are fixed. Units of collar were well compacted, robust, and of about 1 kg in weight. Shown in Fig. 1 is GPS collar worn on cattle for monitoring.

Two types of sensor were used for the fitting of the collar, they are (1) a temperature sensor: for the recording of temperature for each GPS location fix. The sensor is protected and sensitive to the rapid changes in temperature (2) motion sensors that are dual axis: record the movement of animal, and are sensitive to the movement of head and movement of neck that are vertical and horizontal. The activities in movement counts stored with other information are recorded by them when GPS position fix is taken, and then, reset to zero. The period of time during which sensors record movement during each fixed interval is user defined. 2-way data transfer between the unit of the collar and the smart phone was facilitated by a network of Sigfox's unique network dedicated entirely to the IoT.

This secure, global network was built specifically to power smart devices. Unlike most first-generation smart applications, devices that connect to the Sigfox network don't rely on WiFi or 4G networks, making the device ideal solution and real "real time' monitoring device. TR20 GPS tracking collar is plug-and-play, so pairing or complex configuration is not required and can be connected to the network in a matter of minutes. Once connected, each device gathers real-time information on the location of an animal, as well as the animal's speed, body temperature and stress level. This information is transmitted to the Internet and made available in a user friendly way to herdsmen on smart phone, tablet or desktop computer. Alert notifications are sent if animal strays beyond set boundaries, or if any behavioural anomaly occurs.

Collar attachment on cattle was accomplished within a few minutes while the cattle were confined in a squeeze chute. The collected data from GPS collars were handled using the proprietary program designed to correct position fix data differentially for increased accuracy. Collection of data for the assessment of static accuracy was made in October, 2018 from a collar.

The collar was placed and centered 1m above a known benchmark of latitude and longitude. Taking of readings was in five minutes intervals for twenty four hours. Three cattle data collections were conducted in November, 2017; May, 2018; and September, 2018. For every collection of data, the GPS fix interval was fixed at five minutes. The utilisation of pasture which its measurement was based on the time spent in each section of paddock was used as a measure to compare the different between collar strategies. For every cell utilisation, the number of GPS fix locations within cell for every cell utilisation was multiplied by interval of GPS fix. The purpose of the percentage was for the comparison of the effect of different GPS fixed intervals or optimal number of animals that are collared. Five minutes fixed interval utilisation percentages were considered the control value against which other fixed intervals were compared.

Antecedently, capabilities of collar were limited to the location of animal without the active grazing indicant. For seven days, the location of GPS fixes was taken every five minutes where the sampling window for activity was set at four minutes between fixes. Remotely, cattle were observed on two occasions, each lasted for approximately eight hours consecutively. The general behaviour of individual cattle at each location fix of GPS during the preceding five minutes was classified as active or inactive due to the grazing status and standing/lying status displayed by the individual cattle.

Counts from activity sensors that are vertically and horizontally made were added for respective four minutes observation windows and data analysis for differences between collars and observed activity for every period were carried out. The cut off value for the activity counter was determined through experimentation that classified the animals' activity. In order for the accuracy of this approach to be evaluated, these data were checked against observed data.

As the requirements of this study are to analyze the movement and grazing patterns of cattle and GPS tracking processing, and as the tracking cattle movement in a free-range during grazing is difficult of which among the various monitoring and tracking algorithms currently available, the most suitable algorithm to use is the global positioning system 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 having health challenges (2) cattle having disease (3) cattle's death. Normal and healthy cattle will behave active, maintain normal body colour 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 behaviour and 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 throughout the day, showing minimal or almost no response to the environment.

Since the cattle exhibit changes in their grazing patterns and behaviour, the GPS will be able to record this and with the application of the suitable algorithm, we are able to model out the behaviour of the cattle base solely on its grazing patterns. The GPS monitoring collar is connected to the network via cloud technology (Fig. 2).

GPS monitoring collar is placed on the neck of the cattle (Fig. 1). As it is positioned round the cattle's neck, a view of the whole paddock enables the grazing patterns and behaviour 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 is also being monitored.

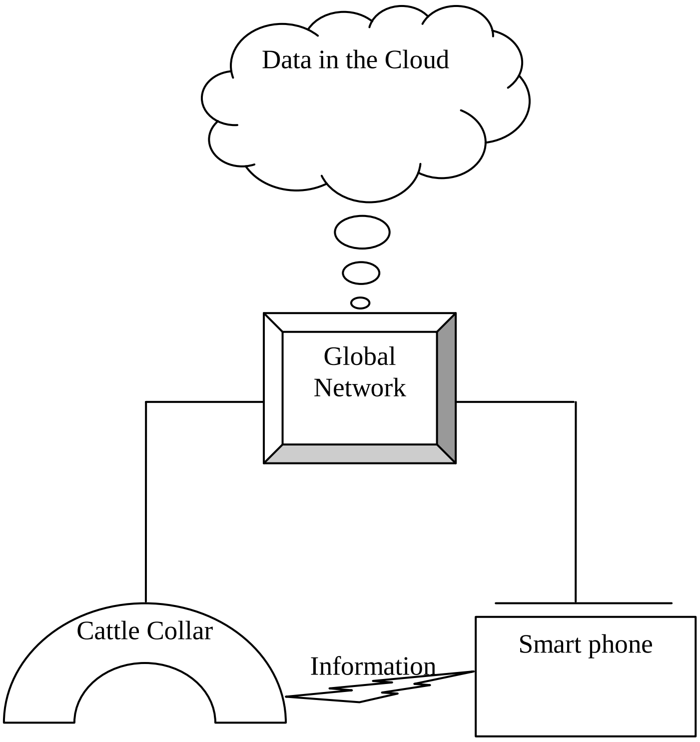

Fig. 2. Diagram of the proposed system

As earlier stated, in achieving this, we made use of multiple sensors which are only sensitive towards a specific agent. 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 flows directly through as inputs and produced an output if a particular condition is met. Any changes with the behaviour and grazing patterns of the cattle in the grazing field especially going beyond boundaries will cause the application to trigger an appropriate alert.

IV. RESULTS AND ANALYSIS

Location fixes for over a day period were showed through testing to be accurate, at roughly 95% for eight minutes of time after correction of the difference. There was no bias of direction on the part of errors that have consistency with other studies' finding. Raising the GPS fix interval from five to thirty minutes proportionally allowed more errors when compared to the original five minutes result as presented in Table 1. Nevertheless, errors for a GPS fix interval were small (approximately 7%) with one animal. Error introduced for more than one animal that worn collared (4%) were roughly 2/3 of a single animal. When collars that were few in number were employed for the modelling of more animals' location, introduced were significant errors as presented in Table 2.

These errors were in the range of 10% when 2 out of 3 cattle were collared and 40% when only 1 out 3 cattle was collared.

Table 1: Error due to raising GPS fix intervals (%)

	GPS fix interval, min		
Test date	5	10	15
Nov., 2017	0	1.9	3.5
	0	**0.4**	**1.3**
May, 2018	0	1.4	2.4
	0	**0.7**	**0.7**
Sept., 2018	0	0.9	2.8
	0	**1.6**	**1.7**
Average	0	0.9	1.2

The error range was roughly 70% of error values when their average was calculated, an indication of variability of big animal. When collars that were few in number were employed, range and error's average were increased. When individual animal in the paddock was expressed, the tracking patterns for individual were unique. There were observed differences in behaviour between collars for activity sensor counts for the same observed behaviour. The implication is that there should be unconstrained standard in the collars mounting for every cow with individual collars calibrated.

Nevertheless, there was difference between the observed active and the inactive sensor count means, indicating the occurrence of successful classification of activity counts.

Table 2: Significant errors (%)

No. of collar	Error	Range
Three	11.9	10.0
Two	13.3	11.5
One	28.4	12.4

Additions of animal sensor count less than 100 within the four minutes periods, between the GPS fixes were classified as inactive, while additions that are either equivalent to 100 or more than 100 were classified as active. 94.8% (128/135) of active data records and 91.2% (1092/1196) of inactive data records were correctly classified for an overall performance of 91.7% (1220/1331) of correctly classified records. The high percentage of classification that is correct serves as assurance that predicting animal activity accurately was accomplished. Relatively well distributed were the grazing location fixes in classification that is active.

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The inactive fixes that were near to water in their location or in favourite places for resting were clustered. Employed for the estimation of the amount of grazing time for individual cattle were active versus inactive classifications in data (Table 3).

Table 3: Grazing time estimation (%)

No. of collar	Time spent grazing (%)
2	21.3
5	23.3
7	22.4

V. CONCLUSION

This paper has presented a framework for real time cattle monitoring using multimedia networks. The behavioural change exhibited by cattle during grazing was a reflection of so many happenings during grazing. These behavioural 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 in order to identify the factors reacting to the cattle.

As there are different species of animal, so also there are different behaviours exhibited by these animals. The behaviour of livestock, wild animals, and domestics animals are not the same. And the taxonomy of animal does not guarantee the same behaviour from them. This is a challenge for monitoring the behavioural 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 behaviour of the very stubborn cattle, virtually monitoring cattle to restrict their movement.

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AUTHORS PROFILE

Rotimi-Williams Bello holds Bachelor of Technology in Mathematics & Computer Science (FUTMINNA, Nigeria), Master of Technology in Computer Science (FUTA, Nigeria). He is a Ph.D. student with the School of Computer Sciences, Universiti Sains Malaysia, 11800, USM, Pulau Pinang, Malaysia. His area of research includes Vision & Image Processing, Computer Security & Cryptography, Machine Learning & Data Mining. He is a professional member of the Nigerian Institute of Management (Chartered).

Professor **Dr. Abdullah Zawawi Hj** Talib is with the School of Computer Sciences Universiti Sains Malaysia, 11800, USM, Pulau Pinang, Malaysia. He has a Bachelor of Science from Bradford, U.K., Master of Science from Newcastle Upon Tyne, U.K., and Ph.D. from Wales, U.K. His area of specialization includes Computer Graphics & Visualisation, Geometric Computing & Scientific Computing.

Dr. **Ahmad Sufril Azlan** Mohamed is with the School of Computer Sciences Universiti Sains Malaysia, 11800, USM, Pulau Pinang, Malaysia. He has BIT (Hons) from Multimedia University, Malaysia, Master of Science from the University of Manchester, United Kingdom, and Ph.D. from the University of Salford, United Kingdom. His area of specialization includes Image Processing, Video Tracking, Facial Recognition & Medical Imaging.