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A NOVEL APPROACH OF CATTLE HEALTH MONITORING SYSTEM BASED ON WIRELESS SENSOR NETWORK FOR EARLY DETECTION OF DISEASE

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Abstract- Early diagnosis and treatment of sick cattle may be even more important than the type of treatment administered. The aim of this study was to prioritize the objectives of research into new sensing systems to monitor routinely the health of dairy cattle. The proposed monitoring system includes the infrastructure, hardware, software and representative physiological measurements. This setup will be capable of continuously assessing the health of individual cattle, aggregating these data, and reporting the results to owners and regional authorities could provide tremendous benefit to the livestock industry. Monitoring methods that rely on transducers to detect sudden body temperature change has limited specificity and high numbers of false positives unless supported by robust models to integrate data from a number of sources. Body temperature plays a major role in the detection of ill health. The temperature data can be collected using wireless sensor network and the collected data can be used for early detection of diseases. This paper presents results from a prototype wireless body temperature monitoring system that utilizes wearable technology to provide continuous animal health data. The infrastructure, hardware, software and representative physiological measurements are discussed.
Keywords- Health Monitoring System, Temperature Monitoring System, Wearable sensor, Data-Acquisition, Wireless Sensor Network.

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Introduction

In this project, we have used a thermometer to measure the temperature of the body. The unit of measurement is degree centigrade (°C). The normal temperature of cattle is 37°C to 38.5°C. We measure the body temperature of animals by placing a thermometer in the anus [4]. The normal animal body temperature readings are listed in the table 1 [4].

Table 1- Normal body temperatures

Animal	Normal Temperature °C	Normal Animal	Temperature °C
Cattle	38.5	Calf	39.5
Buffalo	38.2	Goat	39.5
Sheep	39	Camel*	34.5 - 41.0
Llama	38	Horse	38
Donkey	38.2	Pig	39
Chicken	42	Piglet	39.8

Body temperatures may be 1°C above or below these temperatures. If the animal body temperature is above the temperature range provided in Table 1 then this is a sign of ill health [3]. When an animal has a high temperature it has a fever.

Literature Review

An Integrated Cattle Health Monitoring System" described about an advanced monitoring tools, a distributed software infrastructure, and processing algorithms will allow the livestock industry to react and to predict disease onset in cattle [1].

Integrating RFID withWireless Sensor Networks for Inhabitant, Environment and Health Monitoring" described about a specific system call Hybrid RFID and WSN System (HRW) to integrate the RFID and WSN technology, which overcomes their disadvantages and puts their advantages to a good cause. The HRW is composed of Gateway RFID readers (GRFID) and Hybrid Smart Nodes (HSN) [2].

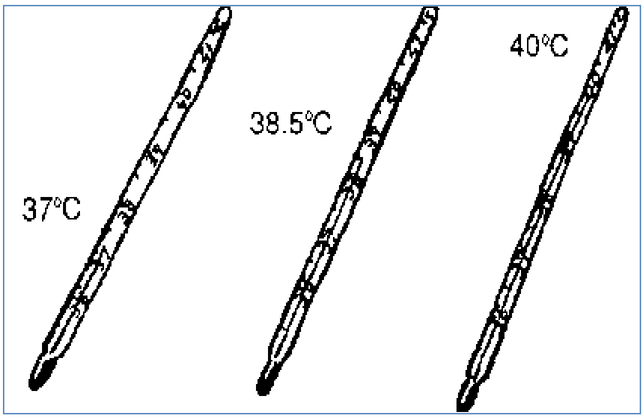

Fig. 1- Manual temperature measurement using thermometer.

Fig. 2- Cattle is ready for the test

Proposed Model

The overall research of the project is to monitor the health condition of the animal using a wireless sensor mote. The sensor mote contains in-network processing algorithm for improved health monitoring and routing of health data [1]. These systems will improve the ability of the livestock industry to react and to predict disease onset for epidemiological spread. Traditionally, cattle health has been ascertained by visually assessing animal behaviour or by manual inspections from a farmer or veterinarian [3]. This is time-intensive and can realistically not be performed often. In this research, each time animal data are uploaded to a base station, the offline processor could analyze them to detect abnormalities. Animal status could then be easily summarized as discrete states of health, such as well, suspect and abnormal. These data could be sent to regional and national collection centres that monitor the health of many herds, providing data to spot larger trends and support epidemiological research [2]. This information, in concert with previous trend data, can then be used to generate a regional “health weather forecast” that can notify veterinarians, ranchers and emergency responders that animal health concerns, possibly exacerbated by projected weather patterns, and are imminent. Sensor nodes collect the data of interest (e.g., temperature, heart rate, animal location, etc.), and wirelessly transmit them, possibly compressed and/or aggregated with those of neighbouring nodes, to other nodes. WSNs can be used to monitor remote and/or hostile geographical regions, to trace animal movement, to improve health weather forecast, and so on [5].

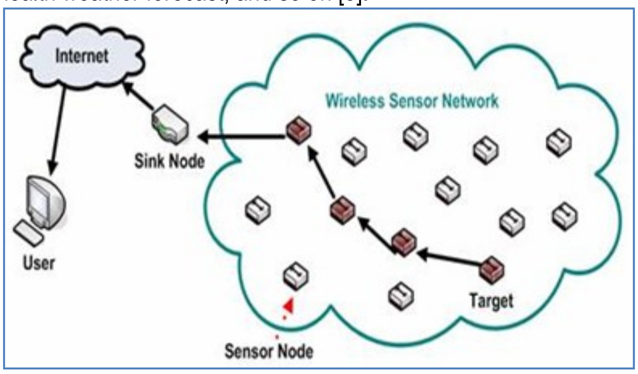

Fig. 3- Wireless sensor network configuration

Prototype Design of Health Monitoring System for Cattle

This system contains a transmitter, which transmits the health record and a unique identification number [3]. This monitoring equipment periodically records the animal's core body temperature, head motion, and absolute position (via GPS), as well as the temperature and humidity of the surrounding environment. According to wireless sensor network, ZigBee-compatible centralized nodes will be placed in areas of high animal traffic such as water troughs, feed bunks and shelters [1]. Whenever any cattle wanders within range of the centralized wireless sensor node, the buffered health data are uploaded to the centralized node which will again transmit to the main base station for better analysis and storage of data [3].

Measurement Parameters

Body temperature [Fig. 4.] and heart rate may be compared to known trends in circadian rhythm [Fig. 11.] over the course of a day. Deviation from the norm is a good initial indicator of aberrant behavior and possibly illness. We also plan to use animal head motion to assess behavior, a method that has several advantages [2]. A head motion sensor is a simple device that can be packaged inside a small enclosure and placed on an ear tag or halter. The motion sensor data has to be sampled at 50Hz or greater per channel, for better signal acquisition [1]. An on-board algorithm can be developed to classify head motion into different types of behavior that can be stored as few bytes per minute rather than many bytes per second. A GPS device can also be implanted for the exact location of the cattle, which is required for a complete behavioral profile study. The behavior can also account for observed fluctuations in heart rate and temperature, allowing a better activity and health record to be compiled [1].

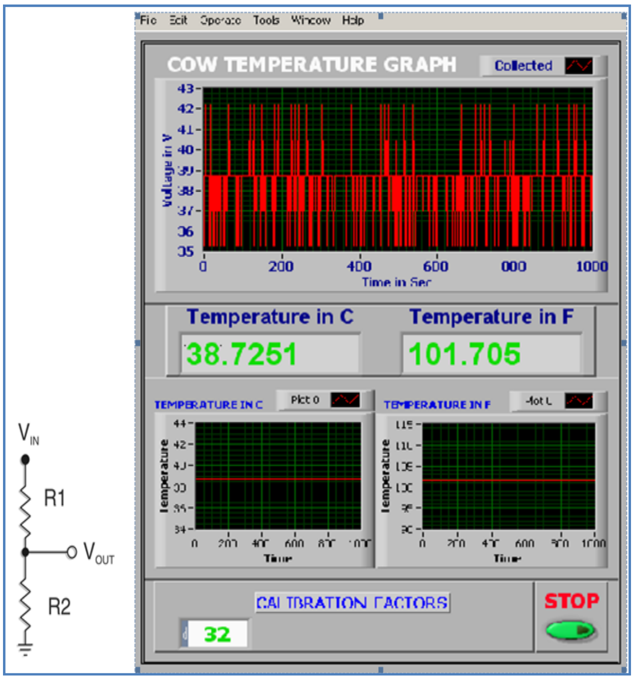

Fig. 4- Body temperature Measurement for single cattle. [R1: RTD, R2: Fixed Resistor, VIN: +5v, VOUT: NOISY OUTPUT)

Prototype Monitoring System

A single sensor mote contains a temperature sensor for core body temperature measurement, a head motion sensor for detection of angle of movement of the cattle head, a GPS module for the detection of exact location of the cattle, a heart rate sensor for the monitoring of heart pulses using a standard set of electrodes, a surrounding environmental condition monitoring module [Fig-5].

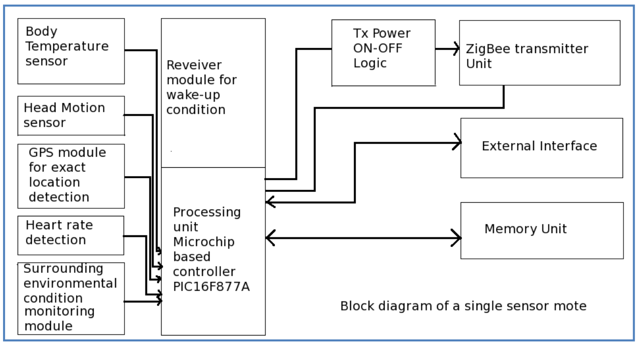

Fig. 5- Block diagram of a single sensor mote

This system is unsuitable for long-term deployment since the sensors require a conductive gel to maintain good electrical contact with the skin; the gel can dry up or the electrodes can move out of position within a matter of hours. A head motion sensor is a three-axis accelerometer enclosed in a waterproof casing, which is attached to a halter placed on the animal [11]. The above sensing units are directly connected to the processing unit along with some electronic safety systems. A GPS module is required to detect the exact location of the cattle [9]. To design a cost effective solution of the above system, wireless sensor network based localization and tracking methodology can be used for the detection of the exact location of the cattle [8]. The processing can be done using a core system, micro-controller or microprocessors. The processing algorithm can be downloaded to the micro-controller for standalone mode operation. A receiver module with sophisticated antenna system is required for the implementation of transmitter wake-up conditions [5]. A sensor mote contains some external interface that can be used for program loading and external device interface. The algorithm can be written in any assembly language or any other hardware programming techniques depending on the type of compiler to load it in the program memory. The current prototype consists of custom hardware designed to integrate a collection of sensors and commercial products into one system. The current prototype consists of custom hardware designed to integrate a collection of sensors and commercial products into one system.

When an efficient algorithm for onboard processing of sensor data has been developed, it will be implemented on the core processor or a processor dedicated to the task [1]. This will vastly reduce the memory required for data storage as well as the power required for wireless data transmission. The collected data are transmitted through the animal to the storage system using a 315/433.92 MHz wireless link. The system periodically records animal location and uses time data received from the GPS satellites to accurately timestamp sampled data [1].

Information System Support

The health information can be stored in the base station database and application to assist. The database consists of all the record columns of the cattle health. When an animal comes within the wireless receiver range (i.e. the base node), the wearable sensor senses the measurement parameters and sends the data to the receiver. The animal having a unique ID which associates the animal with the dataset [2]. The viewing application is developed with National Instruments LabView and its tool-kits. Tools like these can aid in the early detection of disease and help subsequent spread of disease.

Communication Protocol

The proposed communication protocol used in this project is a medium access control protocol based protocol (WiseMAC). WiseMAC is a medium access control protocol [Fig. 6] designed for the WiseNETTM wireless sensor network. It is based on CSMA and uses the preamble sampling technique to minimize the power consumed when listening to an idle medium [2]. A unique feature of this protocol is to exploit the knowledge of the sampling schedule of its direct neighbours in order to use a wake-up preamble of minimized size. This scheme allows not only to reduce the transmit and the receive power consumption, but also brings a drastic reduction of the energy wasted due to overhearing. Back-off and medium reservation schemes have been selected to provide fairness and collision avoidance. WiseMAC requires no set-up signalling, no network-wide time synchronization and is adaptive to the traffic load [12]. It provides ultra-low average power consumption in low traffic conditions and high energy efficiency in high traffic conditions.

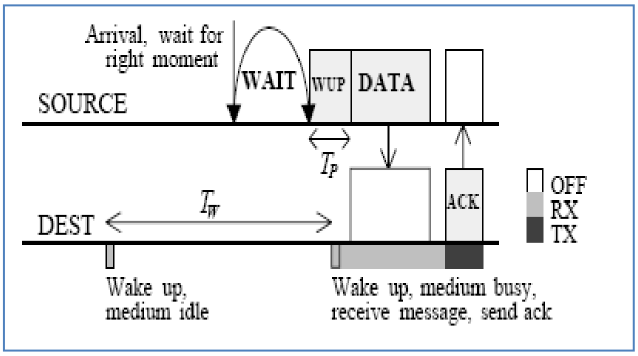

Fig. 6- WiseMAC protocol

Results and Discussions

The temperature data was recorded from the cattle for 1000 samples **[Fig-8]**. The temperature data was having minor variations from the normalized data [**Fig-9**]. The algorithm was used to normalize the noisy data and to eliminate the variations. Some of the voltage readings are listed in the [Table-2]. The temperature readings were recorded using data acquisition card and data acquisition software (LabView). From the table 3, we can observe that, there is a small variation in voltage samples. These variations in voltage readings are due to the motion artifacts occurred during the continuous recording of voltage readings using data acquisition hardware. This motion artifact error is normalized using the algorithm described in the [**Fig-7**].

Table 2- Recorded voltage data from the temperature sensor

Samples	Voltage in Volt	Samples	Voltage in Volt	Samples	Voltage in Volt
	4.0332		4.0434		4.023
	4.0332		4.0332		4.0332
	4.0332		4.0332		4.0332
	4.0332		4.0332		4.0332
	4.0332		4.0332		4.0434
	4.0434		4.023		4.0332
	4.0332		4.0332		4.0332
	4.0332		4.0332		4.0332
	4.0332		4.0332		4.0332
	4.0332		4.0332		4.0434
	4.0332		4.0332		4.0332
	4.0434		4.0332		4.0332

The raw recorded data was plotted as well as the normalized data using Matlab. From the normalized curve we can conclude that the average temperature reading was around 37.75 degree centigrade. The raw temperature data was having motion artefacts error. These noisy temperature readings [**Fig-8**] were processed using the algorithm [**Fig-7**] and the exact body temperature [**Fig-9**] was found out.

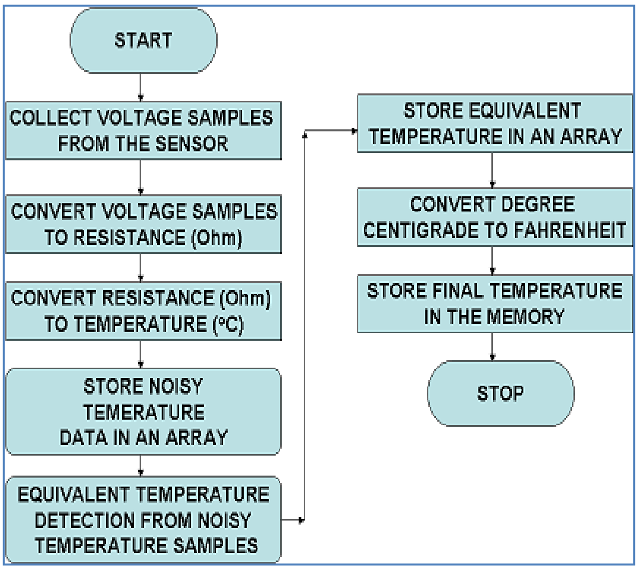

Fig. 7- Flowchart for artefact cancellation in body temperature data

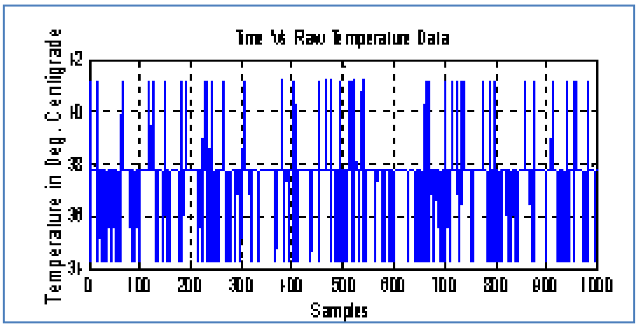

Fig. 8- Raw temperature data plot

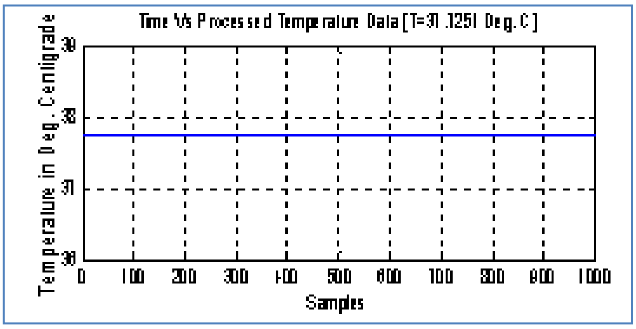

Fig. 9- Normalized temperature data plot

The temperature data was recorded using National Instruments LabView and its data acquisition hardware (NI-USB6008) for 1000 samples [Fig-10] and [Fig-11]. From the Figure 10 we can see that, there is a variation in voltage readings from the baseline due to improper contact with the skin. The rectified noisy data were eliminated and plotted again [Fig-11] to find-out the exact body temperature of the cattle.

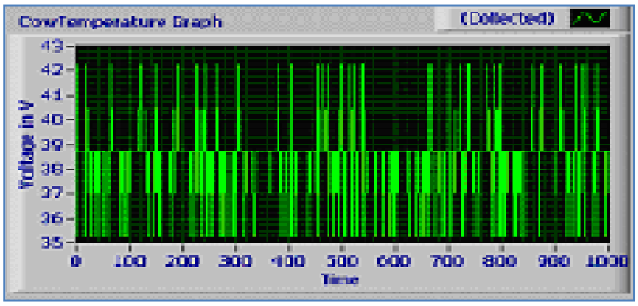

Fig. 10- Raw temperature data for 1000 samples using NI LabView

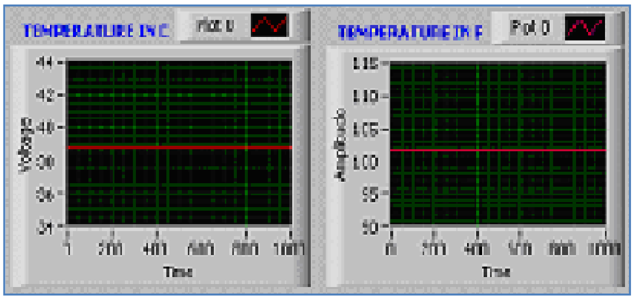

Fig. 11- Normalized temperature reading was seen for 1000 samples

The cattle heart rate was also recorded for 728 seconds and the graphical wave also seen plotted for different samples [Fig-12].

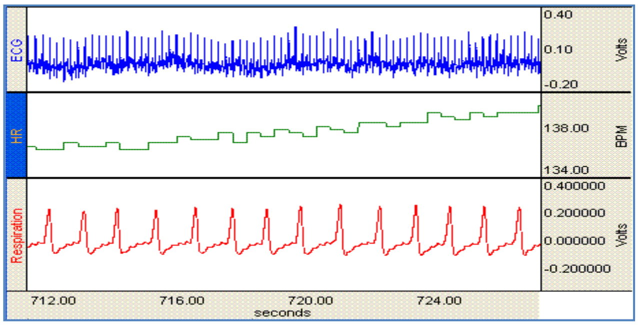

Fig. 12- Normal heart rate pulses of normal cattle

Conclusion and Future Work

Body temperature plays a major role in the detection of ill health. These body temperature variations also affect the milk production of diary cattle. This work has demonstrated the benefits of creating a linked visual-statistical analysis system for animal health monitoring. This paper presented early results from a cattle-worn system capable of acquiring multiple physiological and environmental parameters: core body temperature, heart rate, animal location, ambient temperature & humidity, and motion (via a 3-axis accelerometer). The intimate connection with its immediate physical environment allows each sensor to provide localized measurements and detailed information that is hard to obtain through traditional instruments. More work is required for the analysis of accelerometer data, heart rate and early prediction of disease and information aggregation in a collection of local/regional databases.

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