Section: Personal/Professional Development

***Title*:** Wearable and Wireless: Distributed, Sensor-Based Telemonitoring Systems for State of Health Determination in Cattle

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Notes Text

Abstract

The livestock industry can benefit tremendously from systems that continuously monitor and assess cattle state of health, allowing the industry to maximize meat quality, react to the presence of disease, and prevent its spread. This paper describes early efforts to develop a wearable monitoring system for cattle and its accompanying information infrastructure. The current system employs a suite of sensors for monitoring heart rate, core body temperature, blood oxygen saturation, respiratory rate, activity, ambient temperature, ambient humidity, and global position. Data from these sensors are collected by a low-power, embedded unit worn in a cow bell or collar. They are then collated into a data stream that can be periodically uploaded wirelessly to a Bluetooth-compliant monitoring station and/or handheld computer that comes within close proximity to each animal. These monitoring stations will eventually exist near cattle congregation points such as feed bunks and watering tanks. Algorithms currently under development will perform preliminary state-of-health analyses on local data prior to uploading feedlot/ranch summary data to regional databases, where these data can then be correlated with weather patterns and herd health information provided by other producers. Substantive findings will then be broadcast to veterinary personnel, producers, and government authorities.

I. MOTIVATION

To improve the quality of livestock products and reduce the threat that disease (whether from natural events or bioterrorism) poses to the agricultural industry, the United States must make a quantum improvement in its ability to monitor animal state of health, track animal transport, detect disease onset, and prevent its epidemiological spread. The European Union, Canada, and other countries have already initiated herd monitoring programs [1,2]. The closest thing to a U.S. national tracking system is the National Farm Animal Identification and Records (FAIR) effort, a dairy-oriented pilot project in its fourth year of task force meetings and demonstrations [3]. As evidenced by recent U.S. legislation, mandatory livestock tracking may soon be a global requirement. ***Identification systems permit movement tracking, but they do little to provide early warning signals for potential disease outbreaks.*** Additional sensors are needed to monitor (a) cattle movement to feed and water, (b) time spent feeding and feeding interval [4-6], (c) animal activity [7-9], and (d) physiologic parameters such as core body temperature, thermal profiles [10], heart rate, and respiratory rate.

II. RESEARCH GOALS

The overall goal of this project is to research and develop a technology-rich monitoring infrastructure to support continuous assessment of cattle state of health in concentrated and distributed herds. We plan

to place Bluetooth-compliant monitoring stations near cattle congregation points (see Figure 1). These stations will upload data from nearby environmental sensors and Bluetooth-enabled cow bells/collars, where the animal-worn units will communicate with global positioning, environmental, and biomedical sensors that are either worn by the animals or come within close proximity to the cattle. After preliminary health analyses are performed for both individual animals and the herd, these findings will be archived locally and then uploaded to a regional database so that they can be correlated with findings from other regional producers. These aggregate data will be mapped to current and expected weather patterns in an effort to anticipate the potential spread of disease. For this implementation to be successful, the rules for these transactions and the accompanying security mechanisms must be negotiated with stakeholders within the context of current legislation so that a balance can be maintained between societal benefit and the disclosure of protected producer information.

<Warren, Steve - SystemDiagram_256Colors.tif> Figure 1: Cattle state of health monitoring system.

A functional layout for a distributed, Internet-based livestock information infrastructure is illustrated in Figure 2. The entities depicted here include the following:

- **Producer:** The farm/ranch/feedlot where animal data are acquired and initially processed
- **Veterinarian:** Medical professional/group that provides regional animal health services
- **Regional Center:** A data processing and dissemination facility serving a geographic region
- **National Center:** A data processing and dissemination facility serving the nation
- **Knowledge Repository:** An electronic data warehouse that also provides access to specialized processing routines and diagnostic algorithms
- **Emergency Center:** First responders to disease outbreaks
- **National Weather Service:** Access point for weather information to correlate with animal health

Each entity represents a distributed collection of sub-entities and information resources.

<Warren, Steve - FunctionalLayout_16Colors.tif> Figure 2: Functional layout for a distributed, Internet-based livestock information infrastructure (BS = base station; EMR = Electronic Medical Record; IG = Internet Gateway; LAN = Local Area Network).

In this scenario, animal data acquired by the producer (e.g., physiological, behavioral, environmental) are saved into a local electronic medical record (EMR) and then processed to assess state of health relative to previous trend data. These summary data are then uploaded via a secure Internet gateway to a regional center, which aggregates data provided by local farms and feedlots into a geographical health report. This report, 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, are imminent.

III. EARLY EXPERIMENTS

An important component of this effort is the merging of data from disparate wearable/remote sensors and the subsequent transfer of these data over a Bluetooth telemetry link. Our approach has been to use commercial technology to verify the accuracy of novel sensors designed in-house. As expected, cattle-worn commercial systems that monitor even one or two parameters are rare, and systems that fuse multiple sensor data are virtually nonexistent. The CorTemp product (HQI Inc., Palmetto, FL), utilizes a telemetric link between a small transceiver box and a temperature sensitive bolus (a 1 by 4 inch ingestible pill) to monitor core body temperature. When swallowed, the pill lodges in the reticulum of the cow and uploads continuous core body temperature and heart rate measurements to a transceiver box attached to the back of the animal. The transceiver box is compatible with electrode-based Polar belts used to measure horse heart rates, where each belt is positioned around the thorax behind the animal’s front legs. Figure 3 illustrates (A) the CorTemp bolus and transceiver box and (B) the electrode belt. In early experiments, the CorTemp bolus was inserted into the reticulum of a cow via a rumen fistula.

<Warren, Steve - ECG_Pill_EarPlethysmograph_256Colors.tif> Figure 3: (A) Bolus to measure core body temperature, (B) electrode belt to acquire heart rate, and (C) light based sensor to obtain heart rate and blood oxygen saturation.

In one CorTemp and Polar belt experiment, the sensors acquired heart rate and core body temperature values of approximately 70 beats per minute and 102 °F, respectively. Commercial technology of this nature is applied in a limited number of research environments, so it is expensive. Additionally, this system does not provide the suite of data necessary for overall health assessment and animal tracking. Novel sensors, accelerometers, global positioning devices, and other wearable/remote sensors will need to supplement, or even replace, systems like the commercial technology depicted in Figure 3. To this end, we attempted to replicate these heart rate data with a reflectance sensor originally designed for human use. Figure 3(C) illustrates the sensor placement that yielded optimal results. Heart rate was calculated from the plethysmograph (D) by noting the fundamental peak in its Fast Fourier Transform (E). This rate (72 bpm) was consistent with the result acquired by the electrode belt. Blood oxygen saturation calculations based on these data (as performed in traditional pulse oximeters) are currently underway.

Figure 4 illustrates a prototype wireless platform that integrates a sensor suite. The sensor module, controlled by a PIC 18F8720 microcontroller (A), collates GPS serial data from a Trimble Lassen SQ GPS unit with serial I/O (B), red/infrared reflectance data from an in-house pulse oximeter (C), and core body temperature from an HQI CorTemp unit (D). Activity (accelerometer), ambient temperature, and ambient humidity sensors are also integrated into this unit. The sensor data stream is transferred over a wireless link using a BrightCom Callisto 2 module (E) to a Compaq iPaq Model 3870 handheld computer utilizing an Anycom Bluetooth CF-2001 CompactFlash Card. These devices communicate with one another using the Serial Port Profile (cable replacement mode) in the Bluetooth standard.

<Warren, Steve - PrototypeHardware_256Colors.tif> Figure 4: Prototype monitoring system.

IV. CONCLUSION

This effort addresses a critical need: applied research that will allow the veterinary profession to react to and predict disease onset in cattle. Through development of a physiologic monitoring toolset, a distributed software infrastructure, and new processing algorithms, we can improve the financial stability of the livestock industry while becoming better prepared for epidemiological disasters, whether from natural or terrorist events. As demonstrated by the devastating impact of foot-and-mouth and mad-cow disease on the European farming industry, disease epidemiology needs much greater support at the local level. Economic benefits to producers will be significant: these systems will enable them to assess and treat animals sooner, optimizing meat quality while preventing the spread of disease.

ACKNOWLEDGEMENTS

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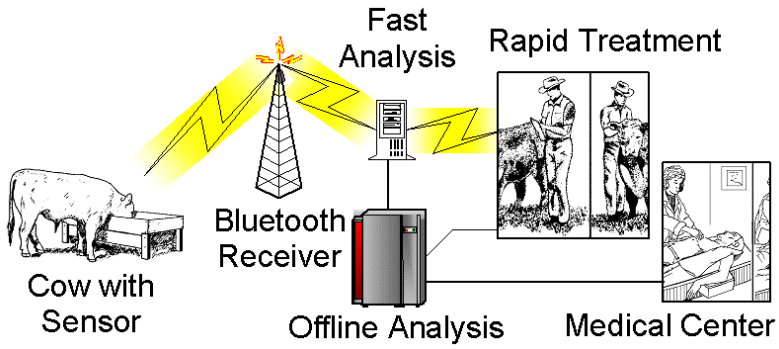
Figures and Tables



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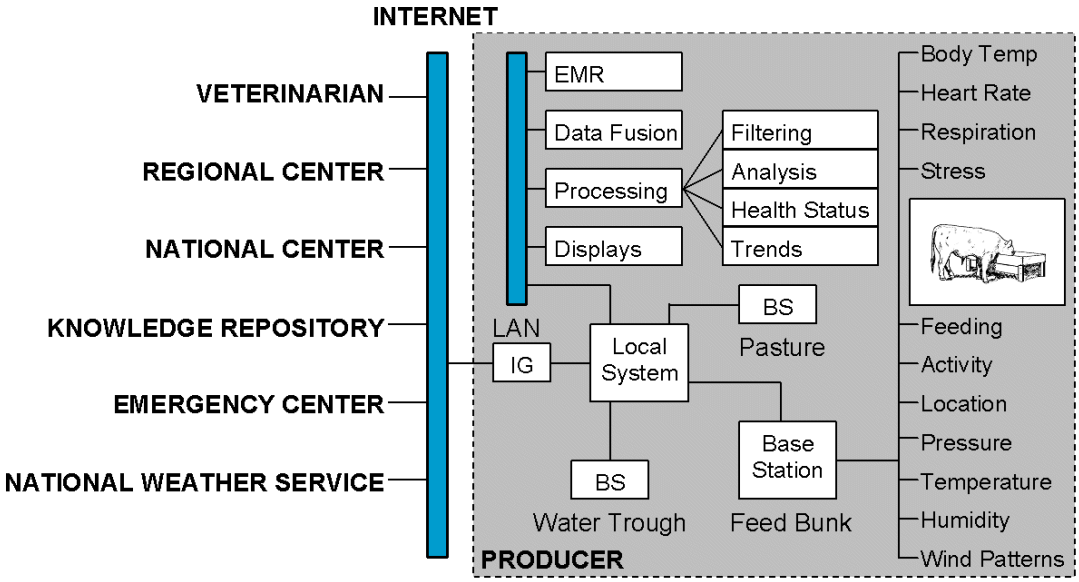

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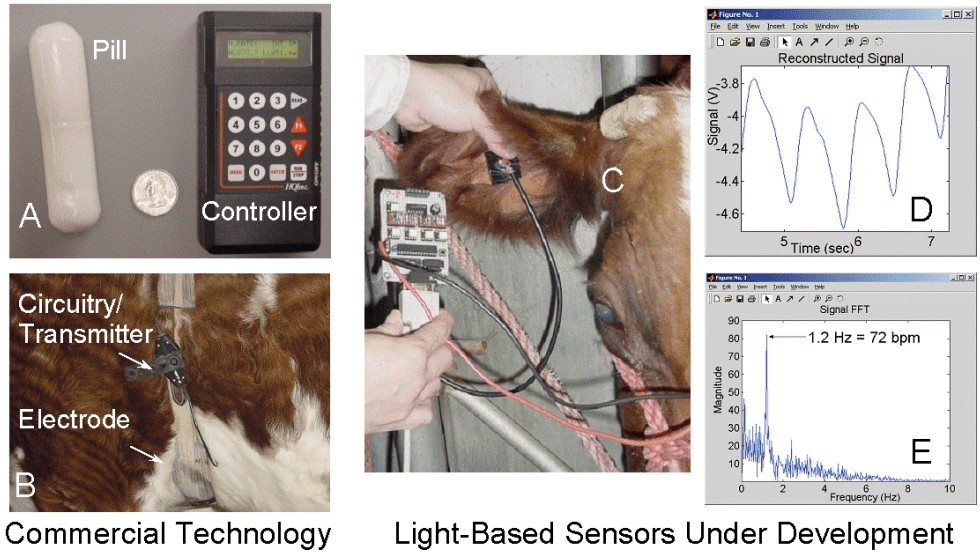

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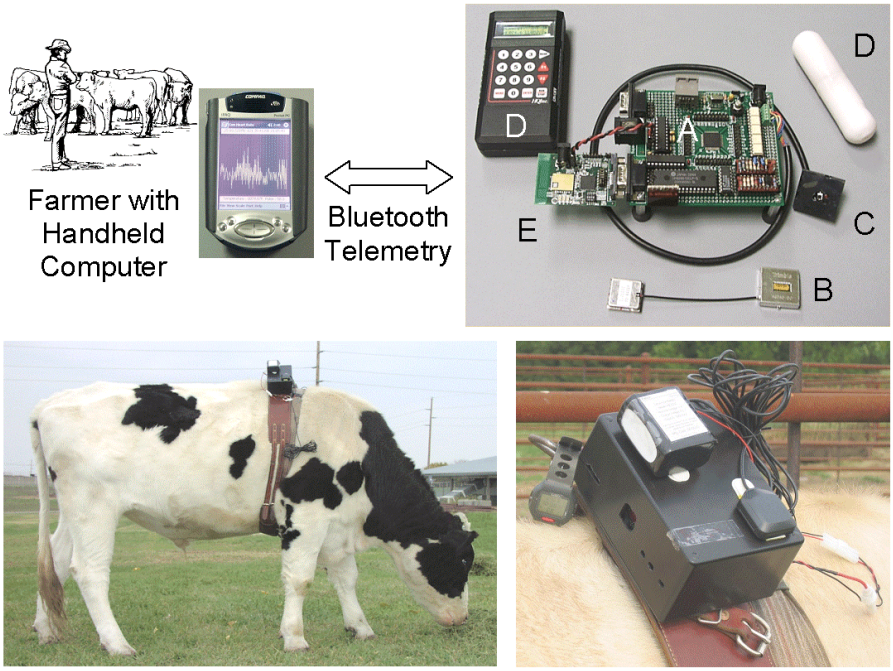

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