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DEVELOPMENT OF A LOW-COST GPS HERD ACTIVITY AND WELFARE KIT (HAWK) FOR LIVESTOCK MONITORING

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ABSTRACT

The objective of this study was to develop a low-cost, automatic and continuous Herd Activity and Welfare Kit (HAWK). The operational goal for the GPS HAWK was to collect GPS positions and analog sensor data at a user-specified sampling frequency and store it in a secure format. The GPS HAWK uses a Garmin 12-channel, WAAS corrected, low-power GPS receiver with <3 m accuracy. The microcontroller-based system is equipped with six (0-5V single-ended, 10-bit resolution) analog to digital (A/D) conversion channels as well as 16 general purpose I/O pins that can be configured for digital operations or serial communication. Data is stored to an EEPROM device and offloaded daily to a 32MB Compact Flash memory card. Power is supplied using a 6VDC, 7.2Ah sealed lead acid battery. The GPS HAWK was enclosed in a weatherproof enclosure and mounted above the shoulders to provide better satellite visibility to the receiver and to prevent contact with concrete feed bunks in confined animal feeding studies.

KEYWORDS. Animal behavior, animal welfare, data logger

INTRODUCTION

Traditionally, animal location within a field has been monitored by visual observations relying on natural hide color or artificial features such as colored collars or tags (Turner et al., 2000). Turner et al. (2000) stated that not only is visual observation labor intensive, problems can occur due to observer fatigue, study area accuracy and physical limitations, alteration of cattle movement due to observer presence and visibility factors due to night and weather conditions. Researchers have utilized global positioning system (GPS) along with geographic information system (GIS) to assess cattle behavior and pasture utilization (Turner et al., 2000; Bailey et al., 2004); to determine beef cattle water intake rates as affected by stream access (Bicudo et al., 2003) and to develop best management practices to reduce non-point sources of pollution (Koostra et al., 2003). Anderson (2000) is developing a "virtual fence" through the use of GPS collars in an attempt to reduce labor costs associated with fence construction needed for rotational grazing.

Advances in GPS technology have provided remote means of monitoring position at < 3 m accuracies over selectable sampling intervals. These capabilities make possible objective measurements for studying spatial and temporal distributions of beef cattle. Spatial analysis of animal distribution using GPS will potentially allow researchers to monitor the animal'[1]s thermal comfort during periods of heat stress among other things.

Several companies market GPS collars (Advanced Telemetry Systems, Lotek, and Telemetry Solutions, for example) for tracking animal movement patterns. The units were initially developed for wildlife monitoring over several hundred miles of terrain requiring only one or two GPS positions per day. Many units require direct connection to a personal computer to download data. This requires the researcher to remove the unit and replace it with a secondary unit or repeatedly capture animals for each download. Most units can store only a limited

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number of GPS fixes and several of the units monitor activity and external temperature. Many of the GPS collars examined could increase spatial accuracy through differential correction by post-processing the data. Post-processing means to manually compare the data received from the GPS tracking unit to data collected from an accurately known location and correcting for spatial errors.

GPS collars that are large enough for beef cattle cost approximately $3000/unit plus cost of software. Hence, monitoring multiple animals over multiple plots becomes extremely cost prohibitive. The objective of this study was to develop a low-cost, automatic and continuous Herd Activity and Welfare Kit (HAWK) with increased GPS accuracy and peripheral sensor capabilities.

MATERIALS AND METHODS

GPS Receiver

Several characteristics were considered when choosing a GPS receiver including accuracy, weight, power, complexity and cost. Many of the GPS receivers (OmniStar, Trimble, Starfire, etc.) currently used in precision agriculture, though highly accurate, were eliminated due to their bulky size, excessive weight and power consumption. Furthermore, most of these systems are relatively expensive making it cost prohibitive to monitor more than one animal at a time.

The receiver selected for this application (GPS 18 LVC, Garmin International, Inc., Olathe, KS) is disk shaped and measures 61.0 mm diameter x 19.5 mm height, and weighs only 115.6 grams. The low-power receiver had a published Wide Area Augmentation System (WAAS) corrected accuracy of < 3m (2drms) and operates at 5.0 VDC (Garmin International, Inc., Olathe, KS). The self-contained unit is weatherproof and considerably less expensive ($76) than many other original equipment manufacturer (OEM) receivers. However, data from this receiver can only be differentially corrected in WAAS mode. The unit does not capture all data required to post-process the data.

Microprocessor

A microcontroller-based system was chosen to serve as the main computing unit for the GPS HAWK. Microcontrollers provide an inexpensive and reliable means to manage sensor data in a prescribed manner with low power requirements. Based on its power management qualities and input and output I/O capabilities the microcontroller (PIC18LF258, Microchip, location) was chosen. The operational goal for the GPS HAWK device was to collect GPS and analog sensor data at a user-specified sampling frequency and store it in a secure format (Figure 1). The microcontroller is equipped with six (0-5V single-ended, 10-bit resolution) analog to digital (A/D) conversion channels as well as 16 general purpose I/O pins that can be configured for digital operations or serial communication. A printed circuit board was designed to house the PIC and all necessary peripheral components. The circuit board also allowed for external connection to the GPS receiver, power supply and test ports. A 4.000 MHz crystal oscillator provided adequate bit timing for serial communication with the GPS unit while incurring a typical current draw of 1.5 mA. The current draw in processor sleep mode could be reduced to 2 µA, but was not implemented due to timing inconsistencies while in this mode.

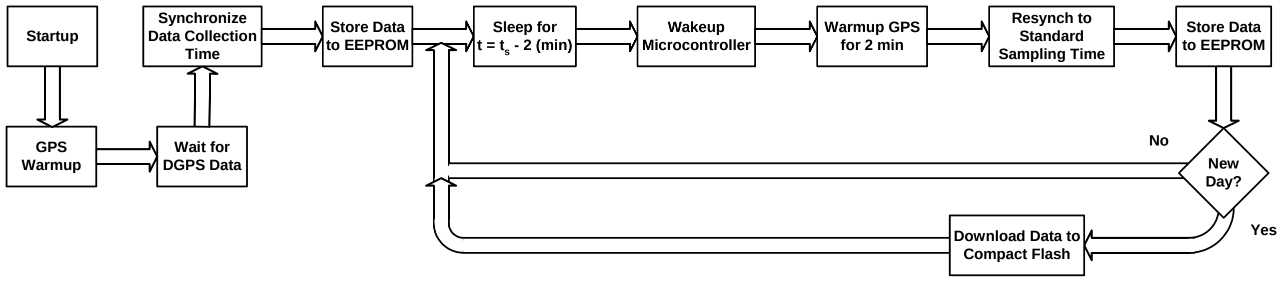

Figure 1. Flow chart of GPS HAWK operation

The unused I/O lines provide substantial future expandability as they can interface with various other digital sensors or peripheral products. Enhanced analog data collection or performance can be attained by utilizing SPI based peripheral conversion chips. Future control routines can also be implemented through available digital output lines.

Program code was developed to enable the microcontroller to record GPS information as well as data from analog input sensors at predetermined intervals. Microcontroller code was compiled using the PIC Basic Pro compiler and transferred to the microcontroller via an EPIC flash programmer both from Micro Engineering Labs, Inc. (Colorado Springs, CO).

<u>Data Collection and Storage</u>

GPS data were collected through an RS232 communication link between the GPS receiver and the microcontroller. Analog data were collected through the internal successive approximation A/D converter of the PIC. The following parameters were collected and stored as ASCII characters: latitude, longitude, number of satellites in view, differential correction status, time, date, sensor data, and a unique unit ID number.

The GPS data string contains 32 ASCII characters of interest, thus 32 bytes of data will be stored per message. Each sensor (A/D) channel will also require 2 bytes of data storage and an extra 20 bytes per sample will be set aside for future development work. The total data storage requirement is 64 bytes. These data must be stored in a non-volatile fashion so that if power is lost in the GPS HAWK unit, the data will remain intact. The data should also be stored in a removable manner so that data files can be quickly removed and replaced with blank media for continued measurements. A removable card allows the researcher to capture the animal once, download data and change battery in the field without the need for a computer.

Compact Flash cards were chosen as the data storage media. Upon acquisition of GPS fix and sensor data, the information was transferred directly to a text file stored in a comma delineated fashion on standard Flash cards. Initial testing of this method was successful, but power consumption became problematic as the Compact Flash storage technique required 150 mA of continuous current. A secondary solution was implemented in which the individual sampling information is stored to a serial electrically erasable programmable read-only memory (EEPROM) device. EEPROMs are commonly used in embedded data recording systems, typically cost only a few dollars per unit, are packaged in small footprints, have a nominal current consumption of less than 5 μA, and are readily available in memory packages up to 65 kbytes.

The EEPROM was used to store one day of GPS HAWK data. At midnight (0:00) of each day, the PIC would access the Compact Flash device and transfer the 24h data from the EEPROM to a unique data file. Again, this data file was stored in a comma delineated text file and was directly accessible to a personal computer using a Compact Flash interface. The size of the EEPROM was critical in determining the minimum sampling frequency that could be attained while still downloading to the Compact Flash card on a daily basis (Table 1). Using the 64 kbyte EEPROM while monitoring up to four sensors, a sampling rate of less than 1 min could be obtained without storage saturation. Monitoring 5 and 6 sensors with the same EEPROM were slightly above 1-min interval. Sampling at 30 s would require the EEPROM to download data every 12 h to the Compact Flash card.

Data storage capacity on the Compact Flash card was ample as card sizes continue to increase. Current commercial Compact Flash cards have a data storage capacity of 4 Gbytes, estimated to hold approximately 171 years of data if daily files of the maximum size were created. This is well beyond system requirements, but allows for vast expansion of data collection in the future.

Table 1. Minimum sampling interval for various EEPROM sizes to allow daily data files

		Minimum Sampling Interval in Minutes					
No. of Analog Inputs	Total Data Storage Per Sample	2K Bytes	4K Bytes	8K Bytes	16K Bytes	32K Bytes	64K Bytes
0	32	24.96	12.48	6.24	3.12	1.56	0.78
1	34	26.52	13.26	6.63	3.32	1.66	0.83
2	36	28.08	14.04	7.02	3.51	1.76	0.88
3	38	29.64	14.82	7.41	3.71	1.85	0.93
4	40	31.20	15.60	7.80	3.90	1.95	0.98
5	42	32.76	16.38	8.19	4.10	2.05	1.02
6	44	34.32	17.16	8.58	4.29	2.15	1.07
Max	64	49.92	24.96	12.48	6.24	3.12	1.56

Power Management

Power consumption was the limiting factor when determining sampling frequency and length of operation. Initial design requirements stated that the GPS HAWK unit must be able to operate for at least one week without stopping operation to recharge the system. Based on known parameters associated with the microcontroller and GPS receiver current consumption, the required battery power source can be calculated. The required amp-hour capacity needed is directly related to the sampling frequency, as sampling frequency increases, so does the operating time of the GPS receiver and thus the overall current consumption increases (Table 2).

Table 2. Amp-hour battery requirement for 1 week test duration

Sampling Interval (min)	Battery Requirement (Amp-Hour)
2	12.60
4	6.72
6	4.76
8	3.78
10	3.19
15	2.41
30	1.62
60	1.23

Many battery types (alkaline, lithium ion, sealed lead acid, etc.), shapes, and power ratings were examined. Sealed lead acid (SLA) batteries have the highest power density of sealed rechargeable batteries. The battery initially chosen to power the GPS HAWK was an SLA0926 Interstate Battery (6V, 7.2Ah). A 5.0 VDC low-dropout voltage regulator was utilized to provide the greatest operating window as battery power degraded over time. The battery had dimensions of 151 x 34 x 98 mm and weighed 0.82 kg. This battery would last one week when sampling every 4 min or approximately two weeks when sampling at 10-min intervals.

Data sampling every 10 min was slow enough to allow the GPS receiver to be powered down between samples, thus ensuring efficient power management. The microcontroller was programmed to turn the GPS receiver on exactly 2.5 min before the data was to be sampled. This allowed sufficient time for the GPS receiver to acquire a differentially corrected signal. Excitation of the GPS receiver was accomplished via an on-board solid-state relay. The relay was triggered by a digital input supplied by the microcontroller.

Housing and Harness

Several attachment styles were considered: halter, collar, and shoulder mounted. The GPS HAWK was arranged into a shoulder mounted harness largely due to battery weight but also to prevent the unit from coming into contact with concrete feed bunks in confined animal feeding studies. Placing the receiver above the shoulders will also provide better satellite constellation visibility as compared to a collar. This becomes more important when studying behavior of multiple confined animals such as bunching.

The GPS logger was housed in an 89x89x61mm plastic watertight enclosure. The GPS receiver was fastened to the lid and attached to the logger through a watertight grommet. The SLA battery was housed in a separate 180x119x61mm plastic watertight enclosure. The enclosures were selected for the lowest profile possible while adding stability to the internal components. A battery cable linked the two boxes through waterproof grommets. The plastic enclosures were fastened to a harness shown in Figure 2. A nylon webbing strap attached to a felt cinch encircled the animal's girth while elastic webbing was used down both sides of the neck to provide stability to the GPS HAWK.

Figure 2. GPS loggers atop beef heifers during initial installation.

Table 3 illustrates a comparison of the GPS HAWK to other comparable devices to be used with beef cattle. The GPS HAWK was 2 to 5 times heavier (3.37 kg) than other devices; however for a 272 kg animal this would only be 1% of body weight. The shoulder harness arrangement not only distributes the unit's weight but also facilitates GPS HAWK longevity in feedlot research.

Table 3. Comparison of GPS HAWK to several comparable GPS tracking units.

Company	Product Name	Weight (g)	DGPS	Max # Points	Peripheral Sensors
Iowa State University	GPS HAWK	3371	WAAS	unlimited	6-channel adj.
Advanced Telemetry Systems	ATS GPS	1250	Post-Process	8190	Act, Temp
Lotek	GPS 3300	870	Post-Process	5028	Act, Temp
North Star	D-Cell PTT	1000	Post-Process	transmit	Act, Temp
Telemetry Solutions	GPS-Budget	650	GPS	6000	none
Telonics	TGW-3550	850	Post-Process	4320	none

* Act = Activity, Temp = Ambient Temperature,

CONCLUSION AND FUTURE WORK

A user friendly, more accurate, economical alternative to many GPS tracking devices on the market is being developed through this study. The GPS HAWK can be configured to operate at a predetermined time interval; monitoring location as well as six peripheral sensors. Finally, the GPS HAWK unit was a fraction of the cost of all GPS tracking systems researched.

Activities are currently underway to verify reported GPS receiver static accuracies; developing a more ergonomic fitting harness that adds improved horizontal stability; as well as techniques to increase battery life through solar power. The GPS HAWK will be used in summer 2005 to study relationships between animal comfort or health status and the thermal environment.

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