Grizzly Camera for Habitat Use Analysis

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SUMMARY

In order to understand animals, researchers need to go and see what the animals see. However, the researchers presence will often disturb the movement patterns of the animal. This work reviews the development of a camera system that will allow researchers to see what the animals see, undisturbed by a hunman observer. In addition, this work addresses the issue of reference data collection required for the creation of habitat maps from satellite imagery. The objective of the camera system is to obtain a clearer picture of the habitat through which grizzly bears pass and utilize; to increase reference data sample sizes; to gain insights into relationships between bears; and to observe the effect of human development on grizzly bear behaviour. To test the validity of these objectives two cameras have been deployed in the Yellowhead ecosystem of west central Alberta, Canada.

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1. INTRODUCTION

If we consider biodiversity to be something that ensures continued possibilities both for adaptation, and for future use by people, then we may express biodiversity as a function of the number of species supported by a region (Gaston, 1996). If we consider the grizzly bear (*Ursus arctos*) to be an umbrella species (Noss *et al.*, 1996, Williams *et al.*, 1994), that is the species requirements for persistence encapsulate those of an array of additional species (Lambeck, 1997), then any gradual extinction of the grizzly in Alberta, Canada, implies a reduction in biodiversity, and therefore a reduction in the usefulness of our environment. Understanding biodiversity and how it affects the distribution and movements of animals around the landscape is a major objective for scientists, conservationists and natural resource managers alike. It is only through developing this knowledge that animal populations will be managed to meet conservation, sporting or natural heritage objectives (Gordon, 2001).

According to a report by Alberta Sustainable Resource Development (Stenhouse *et al.*, 2003a) the grizzly bear population model used to manage grizzly bear numbers in Alberta is incomplete and will continue to predict exponential growth rates when this is not biologically possible. Stenhouse *et al.* (2003a) suggested modifications so that the model more accurately reflects current conditions. However, the revised model indicated that Alberta's grizzly bear population is a step closer to extinction (Calgary Herald, 2004). Subsequently, Stenhouse *et al.* (2003b) suggested that current prediction models are most sensitive to the quality of base habitat maps and our understanding of habitat carrying capacity for grizzly bears. Given the state of the grizzly bear population, if Alberta wishes to continue developing economically with minimal negative effects on its environment a better understanding of grizzly bear forage resources is desirable, at different time and spatial scales. These patterns can then be analyzed in combination with estimates of the amount and distribution of important habitat attributes.

One of the standard habitat analysis field methods used in wildlife biology is to visit grizzly bear use sites, typically 2-3 weeks after the bear has left the area. However, this often results in the loss of information because animal remains may no longer be found and/or vegetation conditions have changed. Due to logistic considerations researchers are also forced to sample GPS locations and concentrate on the locations that provide easiest access. Finally, it is not possible to understand from the GPS data alone whether a bear has been accompanied by other bears, or is in a location due to association with other bears (Stenhouse *et al.* 2004 in press), or humans, thus affecting the information that can be derived from habitat use data.

Geomatics technologies are ideally suited to address the limitations of these field techniques. Integration of a Global Positioning System (GPS) with image processing and Geographic Information Systems (GIS) can provide accurate and timely reference data for Remote Sensing applications that are typically employed in the production of habitat maps. Over the winter of 2002/2003 the hardware necessary for such an application was investigated and a grizzly bear GPS collar with imaging capabilities was developed. Two cameras were deployed in the foothills of the Rocky Mountains for field trials over the summer of 2003. Additional development and refinement of the system was undertaken over the winter of 2003/2004 resulting in the deployment of two camera systems in the spring of 2004. It is anticipated that approximately 4,000 images will be georeferenced by each collar during the field campaign.

The remainder of this article is structured as follows. In section 2 we discuss the limitations of purposeful sampling and the effect of GPS bias with respect to the selection of sampling sites. We propose an alternative method for the acquisition of reference data and set out the benefits of this methodology. In Section 3 we describe briefly the development of the camera system, the testing procedure undertaken prior to deployment of the cameras, and position this effort in the context of other related work. Section 4 concludes the paper and outlines future work.

2. REMOTE SENSING REFERENCE DATA ACQUISITION

Habitat maps are generally derived from remote sensing imagery. It is rare that remote sensing techniques are employed without the use of some form of reference data. The acquisition of reference data involves collecting measurements or observations about the phenomena being sensed remotely (Lillesand *et al.*, 2004). Congalton and Green (1998) suggest that for classifications of more than 12 categories, a minimum of 75 to 100 samples per category should be obtained. Keeping this rule of thumb in mind means that reference data can also be expensive and time consuming to collect.

Reference data is used to aid analysis and interpretation of remotely sensed data; to calibrate sensors; or to verify information extracted from remote sensing data. This implies that in order for the data to be meaningful, it should be collected in accordance with the principles of statistical sampling designs appropriate to a particular application (Lillesand *et al.*, 2004; Foody, 2002; Stehman, 1999).

Sampling designs, such as simple random sampling are suitable if the sample size is large enough to ensure that all classes are adequately represented (Foody, 2002). Often, however, it is impractical to follow such sampling procedures (Edwards *et al.*, 1998). For example, given site conditions (particularly in mountainous areas), it may be difficult to use randomly located sites, which results in ground data collection being restricted to locations that provide easiest access. Alternative sample designs may, therefore, be required, which may also be influenced by financial and/or practical constraints. Methodologies range from ‘windshield’ surveys to techniques based on double sampling (Kalkhan *et al.*, 1998) and cluster sampling (Stehman, 1999). While there is an obvious desire to balance statistical requirements with practicalities (Edwards *et al.*, 1998), the choice of sampling design influences the reliability of an accuracy assessment (Stehman, 1999).

For this work we are interested in collecting reference data for interpretation and verification of grizzly bear habitat. Current reference data collection techniques have consisted of aircalls from fixed wing aircraft and helicopters, and detailed field observations using standard forestry inventory or ecosystematic classification protocols in random and purposeful sampling strategies. An average of 33 field samples (700 total) were obtained for each of the categories (Franklin *et al*., 2001 and 2002) of habitat data used in the latest Resource Selection Function model for the grizzly bear.

However, the collection of reference data for habitat analysis is also temporally sensitive, in that vegetation conditions vary with time. It is therefore important that satellite imagery be temporally aligned with the reference data acquired for a particular analysis. This is frequently not possible due to the lack of adequate, timely, satellite imagery, and the need to ensure the safety of ground crews working in grizzly bear areas, which may result in the loss of information because vegetation phenology has changed. It is also well known that grizzly bear switch resource preferences as the spring, summer and autumn season's progress (Neilson *et al*., 2002; Nagy *et al*., 1989; Hamer, 1985). Upon den emergence grizzly bear typically search for roots of *hedysarum spp*, horsetail (*Equisetum spp.*) and monocots (grasses and sedges), then switch to Canadian buffalo-berries (*Shepherdia Canadensis*) and blueberries (*Vaccinium spp.*) during the Summer when they enter a period of hyperphagia in preparation for the coming winter. As berry crops come to an end, roots of *hedysarum spp* dominate their diet again. In addition, Resource Selection Function (RSF) models assume a vegetation use because of a GPS position, when it could be associations with other bears, or that a bear is feeding on an ungulate kill, etc. These effects reduce the efficiency of habitat models as a predictor of grizzly bear habitat use.

Given that we are interested in grizzly bear habitat we have developed a digital camera system for the acquisition of habitat imagery in an attempt to improve the current sampling methodology. In effect, each time a GPS position is attempted, an image will be acquired to the side of the bear. It is anticipated that this will provide a timely, and economic, means of acquiring reference data by being able to observe the condition of the habitat in the same state that a bear views it, and by being able to better understand grizzly bear activity at each GPS position.

We anticipate that this form of reference data acquisition will improve researchers understanding of grizzly bear habitat use by removing some of the limitations of purposeful or convenience sampling (i.e., purposeful sampling lacks the necessary probability foundation to permit generalization from the sample data to accuracy of the full population; while convenience sampling does not allow one to assert with confidence that the samples are representative of the population (Stehman *et al*., 1998)), sampling based on GPS positions from grizzly bear without an understanding of the animals activity, etc., and by increasing the sample size used to test the validity of a classification process. However, there remain a number of issues that have yet to be addressed. It has been widely reported (Rettie *et al*., 1999; Dussault *et al*. 1999; Hulbert, 2001; Mech, 2002) that while GPS can provide more accurate, and more frequent, animal locations under all weather conditions it remains prone to non-random errors that are prevalent in other radio tracking techniques. Telemetry bias may result from the animal going undetected in some habitat types; hence imagery will not be able to be georeferenced. Telemetry error may also be greater in some habitat types, which may result in registration errors between satellite imagery and imagery obtained from an animal. This becomes a particular problem when working in areas of high latitude and the animal moves through north facing slopes. In these instances the number of satellites visible to the animal may be substantially reduced, or non-existent, and/or the geometry of visible satellites may be poor, thereby reducing the quality of the telemetry data. With GPS data, the points are usually serially correlated, whereas with standard radio-tracking they often are not. In addition to GPS bias, there is also likely to be some bias associated with a particular animal, which may result in reference data for some habitat types being under sampled relative to their abundance within the landscape, or not sampled at all.

3. CAMERA DEVELOPMENT

The camera was designed to fit a Televilt (Lindesburg, Sweden) GPS-Simplex Predator radio-collar (weight ~1 kg including batteries). The GPS receiver is a 12 channel system that stores the date of each position, latitude and longitude of a position, whether or not the fix was 2 or 3 dimensional, and the Dilution of Precision of the fix. The system is capable of storing approximately 6,000 positions per D size battery (assuming GPS on-time is 60 seconds). The collars also include a VHF transmitter for tracking and remote data uploads (Televilt, 2001) (see Figure 1).

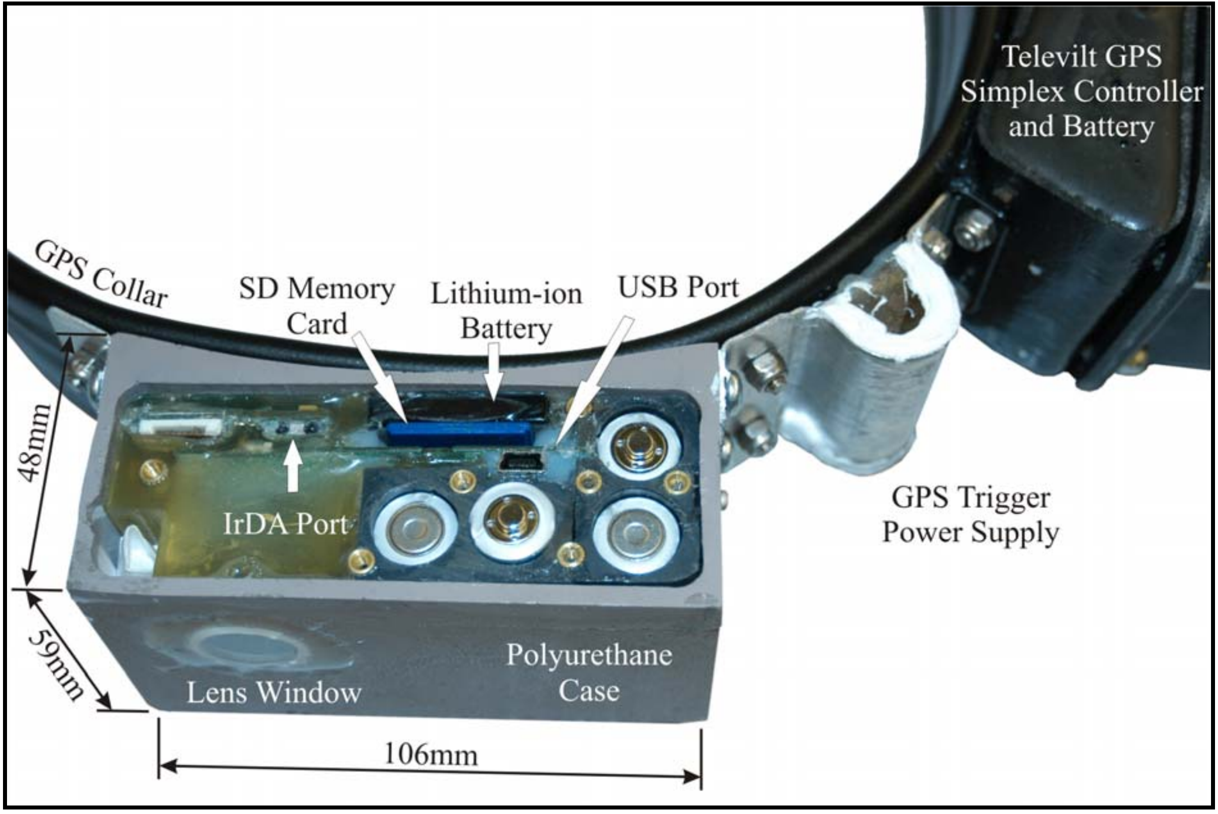

Figure 1: Grizzly Bear GPS Collar and Camera

The main design requirements of the project were to develop a system that was standalone (GPS would continue to function even if the camera failed), and that the finished product be small, light, waterproof and grizzly bear durable. A range of miniature commercial cameras were reviewed with BenQ’s DC1500 being selected for development. The primary reason for selection of this camera was its relatively low power consumption. This was largely due to its use of CMOS sensor technology, rather than the more advanced, and power hungry, CCD sensors that most other equivalent cameras are moving towards. The total weight of the camera was 99 gm including batteries, with dimensions of 5.0cm x 2.5cm x 8.0cm once the casing and other superfluous parts were removed. The camera came with 8MB of built-in flash memory that could be extended with a Secure Digital (SD) or Multi-Media (MMC) memory card. A 512 MB SD card was selected for storage of imagery providing storage for upwards of 8,000 images – significantly more than is possible given the amount of battery power available. The camera is powered by a re-chargeable Lithium-ion battery (capable of approximately 1,400 images at 0˚C). 4 AA (2 pair in series, in parallel) Energizer L91 batteries were selected to power the processor board that controls the camera and recharge the Lithium-ion battery. The L91's are commercial off the shelf batteries that provide the highest power density for their size at the 3V level. The camera system steps the 3V supply to 4.2V in order to charge the built-in Lithium-ion battery. Maximum power consumption observed while the Lithium-ion battery charged was approximately 3.1W. Typical power consumption while the camera was operating ranged from 0.9W-1.95W, and while in sleep mode the system required approximately 0.03W.

A Two Factor (image size and image quality) Factorial Analysis indicated there was no significant difference in visual quality of images taken at 1280 by 960 pixels or 960 by 800 pixels, or images taken at normal or high image quality, indicating that increased resolution or image quality would not provide added benefit. However, it was also determined that images taken at 640 by 480 pixels with normal image quality were acceptable from an operational perspective.

The camera case has been fabricated from polyurethane, and the camera and electronics have been encapsulated in an epoxy mix (see Figure 1 and Figure 2) to provide resistance to shock and vibration, and to exclude moisture and other corrosive agents. Communication with the camera and processor is via a USB port and an IrDA port.

Figure 2: Grizzly Camera - Front and Rear Views

Prior to deployment, testing of the system to determine the durability, and water resistance, of the casing was undertaken, as were temperature tests to determine the effect of temperature on battery life. The durability tests were undertaken with the aid of a mechanical shaker. A wooden box 25mm larger than the camera case was attached to the mechanical shaker, the camera case was enclosed in the box and shaken for a period of 2.5 hours. Upon completion of the shake test the casing was heated to 65°C and then submersed into a 1m deep tank of water. The assumption was that if cracks had developed during the shake test, or the seal between the lid and the case failed, water would have been drawn into the case as the air inside the case cooled.

Data from GPS collars deployed over the last 4 years indicated that the temperature range over a typical field season could range from +28°C to -22°C. Testing indicated that the processor continued to function as low as -42°C, however the camera began to fail to take images once the temperature went below -24°C, and failed completely at -29°C. An additional limitation discovered at low temperatures was that the Lithium-ion failed to charge once the temperature dropped below 0°C. At warmer temperatures, +30°C, system noise increased noticably. We expect that this was largely due to the effect of heat on battery chemistry as the nominal voltage was ~3.30V at 20°C, whereas at 30°C battery volatge was observed as high as 3.75V. Testing indicated that approximately 4,000 images were possible at 20°C, reducing to approximately 1,100 at -20°C. Lastly field trial were conducted on Llama's prior to deployment to validate the the GPS would trigger the camera in an operational setting.

During the summer of 2003 two prototype systems were tested on grizzly bear in the Yellowhead ecosystem of west central Alberta (see Figure 3). The packaging of these prototypes differed from the design deployed during the spring of 2004, in that the cases were fabricated from fibreglass and the electronics were not encapsulated in an epoxy. Cracks in the gelcoat used to waterproof the packaging resulted in technical failure due to water short circuiting the power supply. However, we proved that the images we acquired could play an important role in both habitat map validation and food use models being developed. They also gave some indication of choices that grizzly bears make with regards to human development. We also learned that the bears would accept an additional 300 grams in total collar weight and would not remove the collars because of the addition of the camera unit. Because of the quality of the information from the imagery we believed that continued development of the system, and an increased sample size, will allow the realization of valuable, detailed information about landscape conditions that are favourable for grizzly bears.

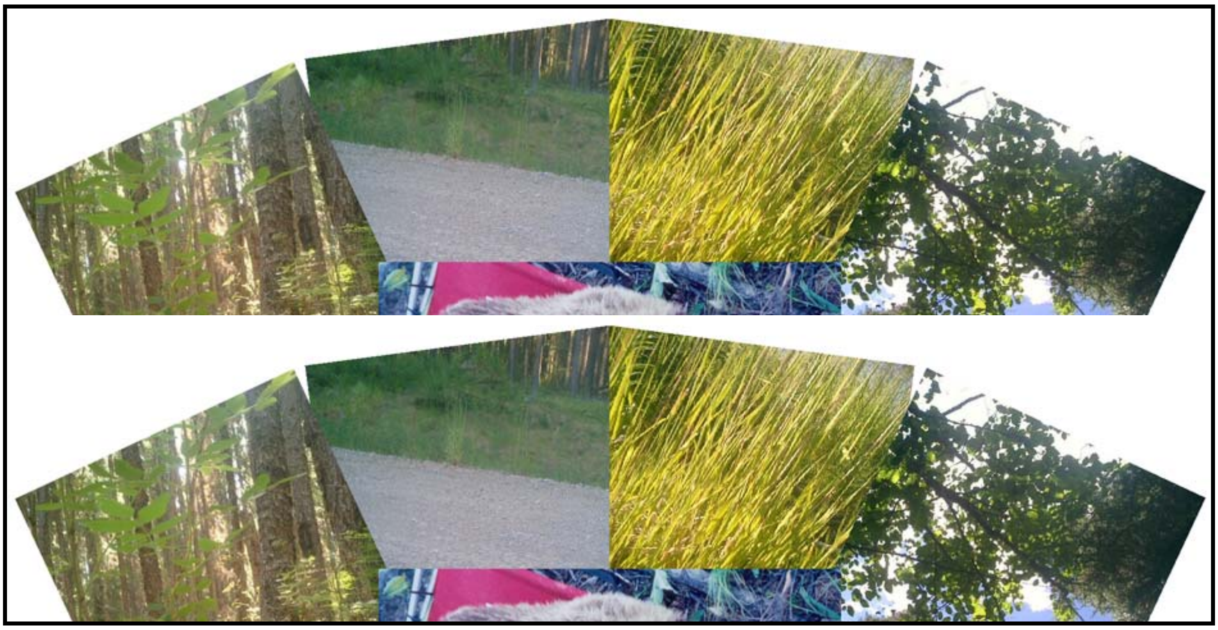

Figure 3: Sample of Images from Grizzly Bear G007, 2003

3.1 Related Work

The use of imaging technology, whether still or video, to aid researchers understanding of animal behaviour and ecology has been available for some time. As far as the authour's are aware the earliest implementation, "Crittercam" (a video imaging system), was developed in the late 1980's by Greg Marshall and National Geographic (National Geographic, 2004). Video imaging systems for grizzly bear have been deployed at the McNeil River, Alaska where the largest known gathering of grizzly bears occurs during the return of Chum Salmon to their spawning grounds (Alaska Department of Fish and Game, 2004), and at Grosse Mountain Refuge for Endangered Wildlife, Vancouver, where they are investigating protocols for the rehabilitation and possible re-release of future orphaned grizzly (Grouse Mountain Vancouver Recreation, 2004). Numerous remote still imaging systems have been deployed in the field to observe the behaviour of grizzly at paticular locations, for example cameras have been placed at some hair snag sites in the Greater Glacier Area Bear DNA Project, Montana, USA (USGS - Northern Rocky Mountain Science Center, 2004). However, this, to the best of our knowledge, is the first attempt to place cameras on grizzly bear to observe their behaviour and the environment through which they travel.

4. CONCLUSIONS AND FUTURE WORK

We have described the development of a tool that uses Geomatics technologies for the acquisition of grizzly bear reference data. We believe that this is the first attempt to integrate a digital imaging system with a GPS collar for the tracking of grizzly bears and observation of their environment. We have demonstrated that the added weight of the camera is not detrimental to grizzly bear movement rates and habitat selection, and initial results indicate that the data collected will be beneficial to the study of grizzly bear habitat use.

There are a number of issues that still need to be addressed with respect to the tracking of animals using GPS. At the present time we do not know what an animal is doing at the time a

GPS position is obtained. We only know that the animal passed through a particular location. It is expected that the imagery collected by the collar will aid our understanding of an animal's behaviour at each location. However, because of the inability of GPS to function under all types of canopy there will be a number of images that can not be georeferenced. The next stage of this work is to develop an inertial based tracking system, pedometer and magnetic compass, which record an animal's movement between GPS locations. It is expected that these paths will enable an animal's movement to be separated into different types of movement. Following Forman *et al.* (1986), Taylor *et al.* (1993) and Tischendorf *et al.* (2000), we can expect that forage patches are connected by movement corridors. By being able to partition grizzly bear movement into locomotion (corridor movement) and specialized search movement (patch movement) it is our belief that we can account for more of the variation in the measured model that is currently used for grizzly bear resource selection functions.

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BIOGRAPHICAL NOTES

Andrew Hunter is currently studying towards a PhD under Dr. Naser El-Sheimy. His research is in the area of Geographic Information Systems (GIS). He has twelve years of spatial data acquisition experience in the cadastral, utility and government sectors including three-plus years GIS management experience. He has been registered as a Licensed Land Surveyor in New Zealand since 1991. Andrew completed a B. Surv. from the University of Otago (NZ) in 1989, and has recently graduated (2003) from the University of Calgary with an MSc. His Master’s Thesis investigated the integration of speech recognition, wireless and GPS components with a wearable computer, all within a Distributed Geographical Information System environment. He is currently working on a research project in conjunction with the Foothills Model Forest Grizzly Bear Research Program developing a camera and motion system for integration with a grizzly bear GPS collar.

Dr. El-Sheimy has 19 years of experience in Geomatics Engineering. His research interests include multi-sensor systems, mobile mapping systems, real-time kinematic positioning, and digital photogrammetry and their applications in mapping and Geospatial Information Systems (GIS). Prior to joining the University of Calgary, Dr. El-Sheimy held the position of VP Research and Development with VISAT Technologies Inc., a high-tech company in Montreal. He has developed software packages for integrating, synchronizing, calibrating, and georeferencing digital frame images using GPS/INS systems. These packages are being used in land-based Mobile Mapping Systems for numerous GIS and mapping applications, some of which are available through UTI. Dr. El-Sheimy is Chair of the International Association of Geodesy's Special Working Group on Mobile Multi-sensor Systems (the IAG SC4-WG1) and the International Federation of Surveyors C5-WG3 on Integrated Positioning, Navigation and Mapping System. He is the recipient of numerous awards for his research work in Mobile Multi-Sensor Systems including the IEEE VNIS Best Paper Prize, The ION Best Paper Award, and the ISPRS Best Young Author Award.

Gordon Stenhouse is the Alberta Provincial Grizzly Bear Specialist and program leader of the Foothills Model Forest Grizzly Bear Research Program, Hinton, Alberta, Canada. Mr. Stenhouse has 24 years of wildlife research experience working in both the Canadian Arctic and Alberta. During this time he has conducted research and management studies on polar, grizzly and black bears, barren ground and Peary caribou, Dall's sheep, moose, peregrine falcons and arctic nesting geese. Most recently the FMF Grizzly Bear Program received an Emerald Award for Research and Innovation in Alberta.

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