Panthera Camera Trap
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Basics

The Panthera camera trap was designed specifically as a wildlife research tool combining low cost, ruggedness, low weight, long battery life, and sufficient picture quality for individual animal identification, particularly tigers. Imaging is digital but without the delays that are common with low cost digital cameras. Figure 1 shows a front view of the camera trap. About the size of a typical paperback book, it is 18.5 cm high, 11 cm wide, 4.5 cm thick and weighs 530 grams when fully loaded with batteries. There are upper and lower sets of slots for straps and a groove across the front face for cable mounting. The overhang above the camera window helps keep the window dry in light rain and often suppresses morning dew formation as well. The camera itself is a square module about 1cm on a side and can be seen in the center of the lower rectangular window. The dark circular window above the camera module is a Fresnel lens used with the passive infrared motion sensor. The rectangular window just above the center is the xenon flash. The power switch is on the bottom left, and next to it is the USB port. These two weatherproof connections are the only user interface needed for normal operation. Access to the interior battery and desiccant compartment is via a screw-on cover sealed with an o-ring.

***Figure 1**. A front view of the Panthera camera trap.*

Hardware Description

Batteries

Figure 2 *- Battery compartment.. The battery compartment is accessed by removing the 6 screws on the back cover. The figure shows the three possible battery configurations that can be used. The batteries are arranged as two sets of 3 in parallel. The camera may be operated with 3 batteries in either of the two configurations on the left or with a full set of 6 batteries as shown on the right*

The lifetime of batteries varies with operating temperature, with low temperatures shortening the life, especially for alkalines. As a rough guide, 3 alkalines will last about 23 days while 6 will provide about 48 days. Low self discharge NIMH rechargeable cells last about 21 days for a set of 3 and 44 days for a set of 6. If operating in a cold climate (sub freezing temperatures) or if maximum battery life is required, it's best to use Lithium primary cells. In one test using a set of 6 Energizer Lithium cells, the camera operated for 72 days.

The battery voltage is monitored by the processor and the camera will shut down when the combined voltage of the cells falls below a specified value. A message regarding this is recorded in a log file stored on the memory card (described below) along with the time and date so the period of inactivity of the camera can be determined.

Desiccant

***Figure 3** – Desiccant compartment. A rectangular opening above the batteries is the desiccant compartment which fits two 5 gram desiccant bags.*

Condensation of water on the inside of the camera reduces battery life due to electrical shorting on the circuit card and can lead to corrosion which dramatically shortens the working life of the camera. The camera seals are designed to prevent liquid water from entering the camera but water vapor in humid air cannot be excluded so desiccant is required to keep the interior dry**.**

Field tests show that the two 5 gram bags of desiccant will be effective at preventing condensation for two months in a warm humid environment. This exceeds the typical battery life so it is convenient to just replace the desiccant each time the batteries are replaced.

Camera Module

A commercially available CMOS camera used in portable electronic devices like smart phones and tablet computers provides all of the imaging function in a small, inexpensive, low power device. These are available as a module with an integrated fixed focus lens that plugs into a socket soldered to the main circuit board. These system-on-chip cameras include sophisticated image processing capability including automatic exposure, color balance, and jpeg image compression that minimizes the need for data manipulation by the main processor. To meet the ultra low power requirements of the portable electronics market, the device incorporates a standby mode which draws extremely low battery current. Importantly, the delay from standby to full power image acquisition is only about 1/100th of a second so fast moving animals will not be missed.

The main processor can issue high level programming commands that cause the camera module to automatically set the photographic parameters such as exposure time, light sensor gains, and color balance values based on real time conditions. Exposure and color balance involve proprietary algorithms provided by the sensor manufacturer and are very effective. However, the processes are iterative and require fairly long times to settle on the proper values, as much as several seconds in some cases. This is too long to wait when capturing images so these adjustments cannot be performed with each triggering event. The solution is to use a simple CdS light sensor (just to the right of the camera module in Figure 1) to monitor general light levels and command the camera module to perform an automatic exposure and color balance whenever the lighting changes by more than a preset amount. The settings are saved and are ready for immediate use when a trigger occurs. This allows full use of the excellent algorithms provided by the camera manufacturer which are much better than relying on the general light sensor reading itself without adding any delay from trigger to capture. Of course, captures cannot be obtained during the times when the camera module is busy, but with a reasonable choice of lighting change condition, +/- 30% for example, the fractional dead time is typically only 1/1000.

A very important criterion for wildlife research, particularly for the tiger census work that motivated the development of this camera trap, is the ability to identify individual animals by their markings. This requires short exposure times to minimize motion blur so the exposure time adjustments made by the camera module are restricted to allow only exposure times of 1/75 second or less. In the event that proper exposure would require a longer time, the camera switches to flash mode. With the xenon flash, exposure is just a few thousandths of a second so low light and night images are always crisp.

Good image quality also requires proper focus. The integrated lens in this camera is a fixed focus type that gives sharp images from just a few feet out to infinity without requiring time consuming focus adjustment.

Image resolution is important but need not be exceptionally high to meet the needs of wildlife research. The megapixel count that is popular in marketing digital cameras is not a good metric for image quality for several reasons. Perhaps the biggest reason is that high pixel counts in inexpensive sensors are achieved via advances in lithographic reduction of the circuitry which cuts the pixel size but also cuts the amount of light that gets captured within the tightly constrained exposure time that is available. This trend has led to a reduction in the signal to noise ratio which manifests itself as noisy images during low light conditions before switching to flash mode. Another reason to avoid stretching the limits of high pixel count is that affordable lenses can’t focus sharply enough to take advantage of the extremely small sensor sizes. Finally, high pixel count translates directly into large image file sizes which reduces memory card capacity and increases data transfer times. The sensor in this camera provides 3 megapixel images which strikes a reasonable balance among the various requirements. The level of jpeg compression is adjustable to allow the user to trade off compressed image quality against file size.

Motion Detector

A passive infrared sensor is used to detect when an animal passes in front of the camera. The PYD1998 digital pyroelectric sensor from Perkin Elmer is sampled about 70 times per second. This high sample rate combined with the very short camera delay allows fast moving animals to be imaged easily. However, a very short delay causes problems with slow moving animals since they need time to reach the center of the frame. Therefore, a novel algorithm is applied to the sequence of sampled sensor readings to trigger the camera module and capture an image when the animal is approximately centered in the field of view regardless of the animal speed.

The motion detector includes a Fresnel lens to focus the infrared emission from a central area of the field of view thereby extending the range of sensitivity to greater distances. The triggering sensitivity can be adjusted by the user to suit the particular application.

Flash

A xenon flash is used for low light and night imaging. This provides brilliant color images with an extremely short exposure time which completely eliminates motion blur. The flash circuit includes a high energy capacitor that can be charged in about 15 seconds. It is kept fully charged while waiting for motion so the flash can be fired without delay. With flash illumination, nearby objects appear much brighter than those further away. This can lead to over exposed images for close animals and under exposed images for those further away. To account for this, the user can choose among various brightness settings that are appropriate for the expected target distance. In trail settings, this would be the distance from the mounting tree to the center of the trail. The image brightness is adjusted using the electronic gain of the camera module rather than changing the light emitted by the flash itself.

Microcontroller and Miscellaneous Electronics

The processor that controls high level camera trap functions is an Atmel microcontroller that features an extremely low power mode of operation that is used while sampling the motion detector. Low power while waiting for motion is critical to achieving long battery life. The Atmel device provides several channels of analog to digital conversion along with digital input/output lines, and integrates a variety of standard bus interfaces like the Multimedia Card Interface used for the Secure Digital (SD) memory card, Universal Serial Bus for the external digital interface, Two Wire Interface for controlling the camera module, real-time clock, and temperature sensor, and Image Sensor Interface for the image data from the camera module. The real time clock chip provides date and time information that is recorded with each image. It uses a coin cell battery to maintain timing when the main batteries are not present. The digital temperature sensor chip records the internal camera temperature which is saved at regular intervals in a log file as well as in each captured image. An inexpensive piezoelectric buzzer is driven with a digital output line and provides an audible signal for various purposes such as indicating a low battery condition on power up. There are 4 dual color LED indicator lights driven by the microcontroller that are used to provide visual indications of various states of the camera as described below.

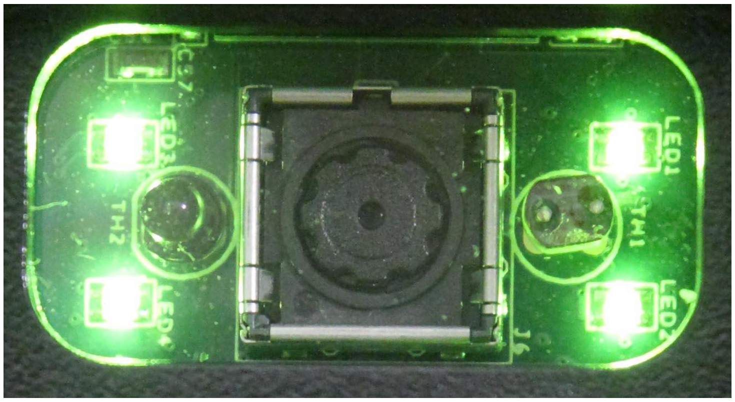

***Figure 4**. This shows a close up of the main camera window. Each LED can be either red or green or off.*

Camera Operation

LED Indicators

Power-On Sequence
The following power on sequence will be observed when starting with no USB device inserted.

All 4 LEDs will glow very dimly for about a second after the button is pushed. The microcontroller is initializing during this time.

Next, the top two LEDs will glow bright red for 8 seconds. The microcontroller is performing tests and checking for the presence of a USB device during this time. There will be an audible beep for the first second as an indication that the processor has started.

After the top two LEDs turn off, a number of green LEDs will come on for about 1 second as an indicator of remaining battery life.
4 LEDs on means there is >=80% remaining life.
3 LEDs on = 60-80%
2 LEDs on = 40-60%
1 LED on = 20-40%
0 LED on = <20%
There is an audible alarm indication of varying pitch lasting several seconds whenever the <20% condition is detected. This serves as a reminder that the batteries need replacing soon.

Following the battery indication, the upper right LED glows red for about 2 seconds as the camera performs an initial exposure adjustment.

Now the lower left LED will come on red (the other 3 are off). This indicates flash capacitor charging and will last about 15 seconds. As the flash batteries get weak, this charge time gets longer. The red LED will start to blink during the last few seconds of the charge up if the batteries need replacement.

After the charging LED turns off, there is a blank period of about 2 seconds followed by a brief green flash of the upper left and lower right LEDs. This signals that the camera is ready to capture images once motion is detected.

Auto Expose Sequence
Depending on lighting conditions, there may be another exposure adjustment required right away and the upper right LED will glow red again for 2 seconds. Following this, the brief green flash of the upper left and lower right LEDs will signal ready again. Throughout the day, as light levels change, the camera exposure will be adjusted and the red LED will come on for a second followed by the green flash to signal ready. Similarly, the flash capacitor needs to be "topped off" by a recharge operation now and then. The lower left LED will glow red during this and the green flash will signal ready after it completes.

Image Capture Sequence
When the camera detects motion and captures an image, both lower LEDs will flicker green for a short period as the image data is written to the SD memory card. If capturing multiple images per trigger

event, the time will increase accordingly. If the image was captured using the flash, the lower left LED will turn red and the capacitor will be recharged. When all operations complete and the camera is again ready, the upper left and lower right LEDs will briefly flash green. If the power switch is depressed during the SD writing, the image in progress will be completed before the camera is shut down.

Shut Down Sequence

After pressing the power button to turn off the camera, the LEDs will light up one-by-one in circular sequence, first in green, then in red to indicate that power is turning off.

Storage, Configuration, and Features

SD Card

The internal memory card in the camera trap is a 2GB micro SD type. All images are stored on this card. They are organized in folders that have a name corresponding to the date of capture of the images. For example, all pictures captured on July 4th, 2011 will be in a folder named 070411. This card also has a file named CAM4nnnn.log in the root folder that contains information about general operation and any errors that may have been detected by the software. CAM4nnnn represents a camera ID which has been assigned to each camera, and nnnn is a unique 4 digit number. This log file contains important information for the developers and takes up very little memory; one year of camera operation uses 0.03% of the SD card which is less than a typical image file. There’s no need to erase it.

SD Card Full

If the SD card fills to capacity during normal camera operation, the camera will automatically shut down to conserve battery power. When the camera is turned on again, the left and right LEDs will flicker on/off in an alternating red/green pattern. In order to return the camera to normal operation, files need to be removed from the SD card.

SD Card Not Detected

If the SD card is not detected or cannot be initialized by the camera at power-on, the top-left and lower-right LEDs will flash red on/off repeatedly every couple of seconds. If the card is in there, turn the camera off, make sure that it's properly seated in the card holder by taking it out and putting it back in again, then power the camera on. If the card is not there, turn the camera off, insert the SD card, and then turn the camera back on.

Camera Configuration

Due to the camera's minimalist design, there are no buttons or an LCD screen. Therefore, the camera's configuration is set up using a computer file instead of buttons on the camera itself. The camera's parameters are mirrored into a file named CamTrap.CTC, which is kept on the SD card's root folder and also automatically copied to USB flash drives. Modifying the parameters in this file will cause the parameters in the camera to update. The CamTrap.ctc file is modified using a computer application called the Camera Trap File Manager.

USB Operation

A USB Type A connector is located on the bottom of the camera next to the power switch. The camera acts as a USB host for certain USB devices. The operations that can be performed using the camera's USB port are as follows:

- Use a USB flash drive to obtain copies of the .jpg files that are contained on the camera's SD card.
- Use a USB flash drive to update the camera trap configuration parameters
- Use a USB flash drive to update the camera's firmware
- Set the camera's clock and location using GPS satellite data by connecting a hand-held GPS - receiver, or a GPS USB dongle.

In the future, the USB connector will also be able to be used to connect a smart phone or tablet computer to the camera. This will enable the ability to view images, set the camera's parameters, and update the camera's firmware from a smart phone or tablet device using a smart phone or tablet software application.

Reading Image Files From The Camera

The images, a log file, and configuration file can all be accessed via the USB port so it is not necessary to read data directly from the SD card. In the preferred mode of operation, called "incremental USB backup", all new images, the log file and the configuration file are automatically copied to the USB drive when the camera is powered on with a USB storage device plugged into the port. The images that are copied are tagged as archived on the SD card and will not be copied again as long as the USB backup mode is incremental. This allows cameras to be periodically read out without having to transfer all captured images every time. Using incremental backups ensures that the complete set of images is preserved on the SD card in case something happens to the USB drive. At the end of a trial, when cameras are returned from the field, the USB backup mode can be changed to "full + delete from SD card" and the next USB transfer will copy all files from the SD card that are not already present on the USB drive and delete all the files from the SD card. Thus, the SD card can be cleared without having to open the card compartment. The reason for including a full copy with the delete is to provide a safety mechanism so that images will not be erased mistakenly. If the same USB drive has been used all along with a particular camera, it will already have copies of all of the images on that SD card and the "full + delete" process will take very little time. If multiple USB drives were used or if images were removed from the USB drive, copying the archived files for that camera onto the USB drive before performing the "full + delete" operation will save time. Alternatively, the configuration option "Quick SD Clean" can be used in conjunction with "incremental USB backup" to delete all image files on the SD card that have been previously backup up to any USB drive. This mode should only be used if it is known that all images files on the SD card have been safely archived to a PC.

Encrypting Images On The Camera

The camera can be configured to encrypt the image files that are stored on the camera's SD card. When this feature is used, image data is encrypted using a password that is set in the camera's configuration.

With encryption enabled, the camera encrypts the image data immediately upon capture and stores it in a file that has the file extension .ENC. These files cannot be viewed until they are decrypted into .JPG files using the Camera Trap File Manager's "Decrypt Image Files" tab. Thus, a poacher who steals a camera will be unable to use the images stored on the camera to help locate animals. The stolen camera will also be useless since the File Manager is needed to alter the configuration file to turn the encryption setting off.

Encryption can be thought of as password protection of your images, and it works as follows. You choose a password which gets stored on the computer on which you are running the File Manager program, and transfer this same password to all of the cameras you are using. Images will only be able to be decrypted using the computer that has the stored password. After the camera images are decrypted, they become ordinary .JPG files that can be viewed on any computer.

Power Lock Button Feature

The camera configuration setting "Power Button Lock" is used to prevent the camera from being inadvertently turned on during transit due to an object bumping against the push button. When the camera has this setting enabled, it will automatically power itself down within seconds of when the button is pressed. Once the camera is ready to be used, this setting must be cleared from the camera configuration. To clear the "Power Button Lock", insert a USB drive and turn it on. The camera will quickly detect the presence of the USB device, clear the power button lock setting from the camera configuration, and automatically shut down. It is now ready for normal operation.

Stealth LED Mode Feature

When this feature is enabled in the camera's configuration, the camera will only use LED indications during the initial power-up sequence, and the first flash charge-up. After that, the LEDs will no longer light up during camera operation.