A Computer-Vision Approach to the Analysis of *Peromyscus californicus* Behavior

Benjamin Manifold*, Thomas Parrish†, Mary Timonin*, Sebastian Pauli†, Catherine Marler‡, and Matina Kalcounis-Rueppell*

*Department of Biology and †Department of Mathematics and Statistics, UNCG and ‡Department of Psychology, University of Wisconsin Madison

Introduction

In this study we analyze the behavior of California mice (*Peromyscus californicus*) at nest sites under experimental treatments that alter male endocrine status. We analyze infrared video recordings of the nest area of mice to validate data collected via radio telemetry and audio recordings. Results will contribute to our understanding of factors that mediate parental care in species that maintain long-term pair-bonds.

Peromyscus californicus

Peromyscus californicus is relatively unique among mammals because it establishes long-term pair-bonds. *P. californicus* lives in small, stable family units in which males and females share equally in defense of territories and care for pups at the nest. This nocturnal mouse is a useful model organism for studying the evolution of mammalian pair-bonding.

Thermal Video and Computer Vision

One method of observing these mice in nature is remotely recording their behaviors at the nest with thermal video cameras. The manual analysis of the thermal video recordings, however, is slow because hundreds of hours of collected video need to processed. Computer vision is a more efficient method of video analysis, and the objective of our work is to automate the analysis of field-recorded thermal video to understand the behavior of wild *P. californicus*.

Previous students involved with this project have developed a method using the OpenCV library and the Sage computer algebra system to automatically process video recordings to extract data describing all animal movement at a site.

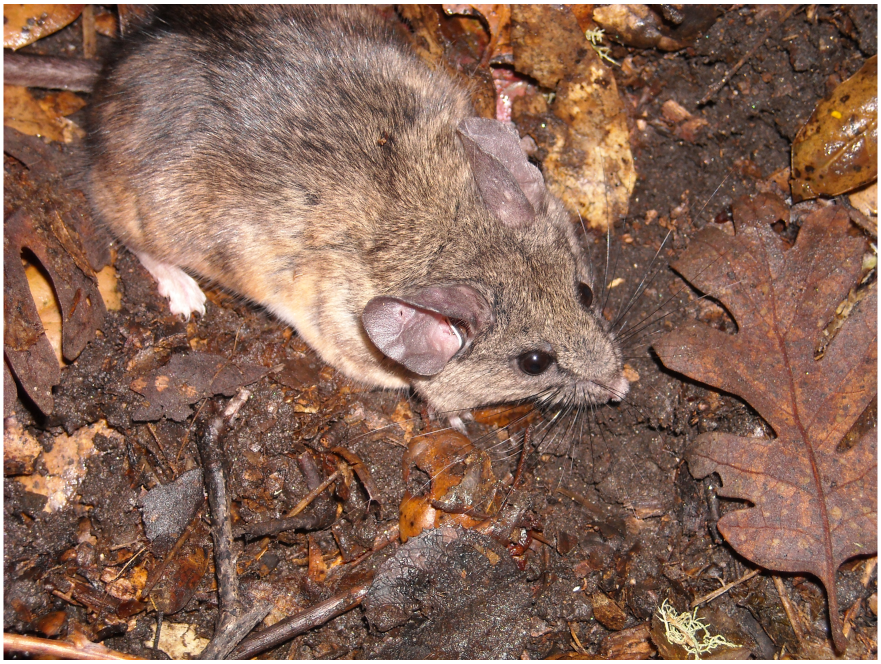

Figure 1: A female adult *Peromyscus californicus*

Field Methods

Nest activity at each nest site was recorded using a thermal-imaging lens (Photon 320 14.25mm; Flir/Core by Indigo) directly connected to a camcorder (JVC Everio DVR) that is used as a digital video recorder. See Figure 2 for a typical camera setup. Recordings were started at dusk each evening, and continued until the hard disk on the camcorder reached capacity (approximately 12 hours). The position of the thermal-imaging lens relative to the nest (height above nest and distance from nest) varied between nest sites depending on where the lens could be placed to achieve an unobstructed view of the entire nest from one side.

Determining Nest Area in the Field

In the field, we marked a 2m radius around the nest structure with flags and took a reference photograph from the same perspective as the thermal lens. These reference photographs were used to define the location of the nest and a 2m boundary around the nest within the thermal videos (Figure 3).

Figure 2: The thermal-imaging lens setup at one of the nest sites.

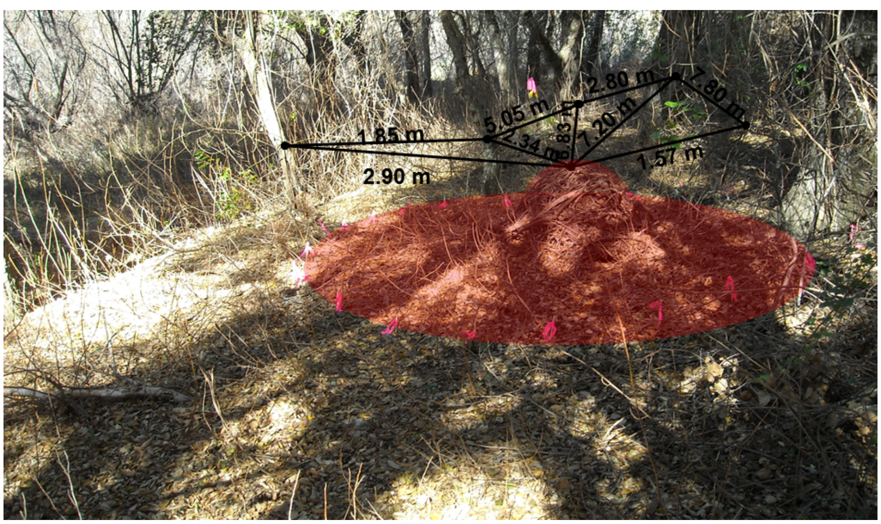

Figure 3: At each nest site, multiple reference images were taken in order to help identify the nest sites within the videos. Field measurements were taken to establish a two-meter perimeter around the nest, marked with flags. Here, the nest area encompassed by this perimeter is shaded in red.

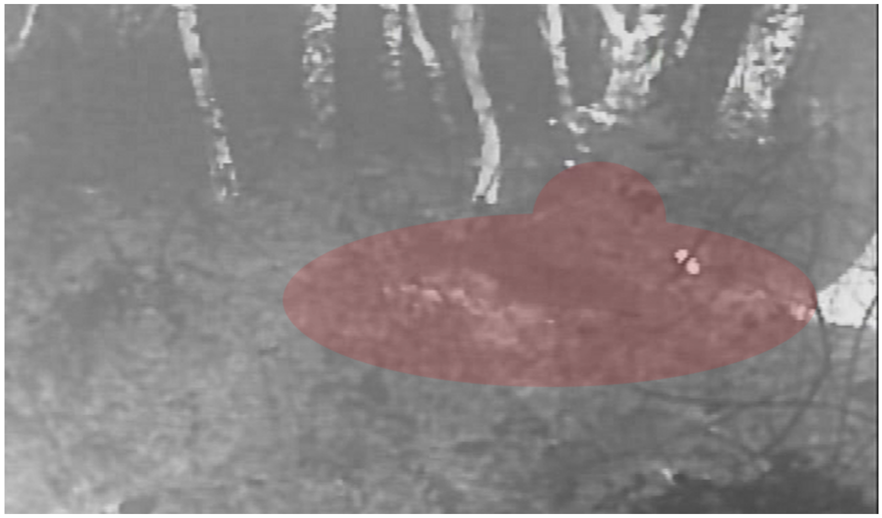

Figure 4: A frame from the thermal video is recorded at the nest site. The flags in the day-time photo and landmarks are used to establish the nest area perimeter in the thermal video stream. When possible, a screen shot of the thermal video was overlaid on the digital photo, and a two meter boundary line was hand drawn, guided by flags in the photograph.

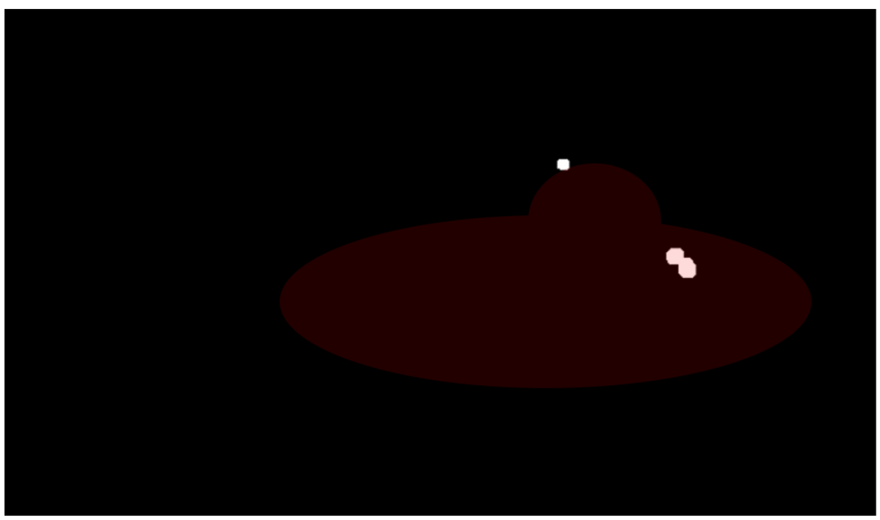

Figure 5: Moving objects (i.e., mice or other endotherms) are isolated from the complex background, becoming blobs. Because of the dynamic nature of the environment, we use the Bayesian background subtraction algorithm described by Liyuan Li, Weimin Huang, Irene Y.H. Gu, and Qi Tian in *Foreground Object Detection from Videos Containing Complex Background*, ACM MM2003.

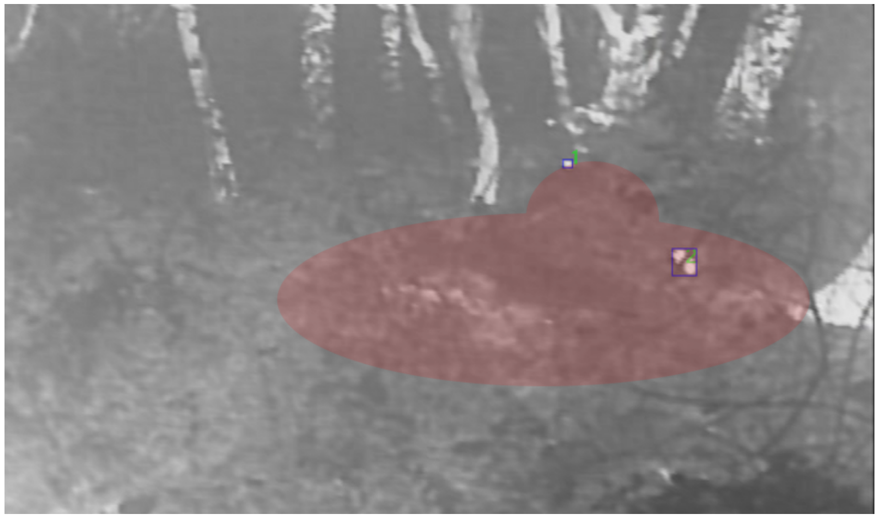

Figure 6: The two blobs in the blue bounding boxes are recognized and labeled. For the labeling we apply the algorithm described in *A linear-time component-labeling algorithm using contour tracing technique* by Fu Chang, Chun-Jen Chen and Chi-Jen Lu (Computer Vision and Image Understanding, 2003) implemented in the C++ library cvBlob , developed by Cristóbal Carnero Liñán.

Figure 7: Track data are extracted frame by frame and then imported into the computer algebra system Sage. To analyze the data we have developed a series of tools and implemented them in Sage. Here we have plotted the positional tracking data from one night of video.

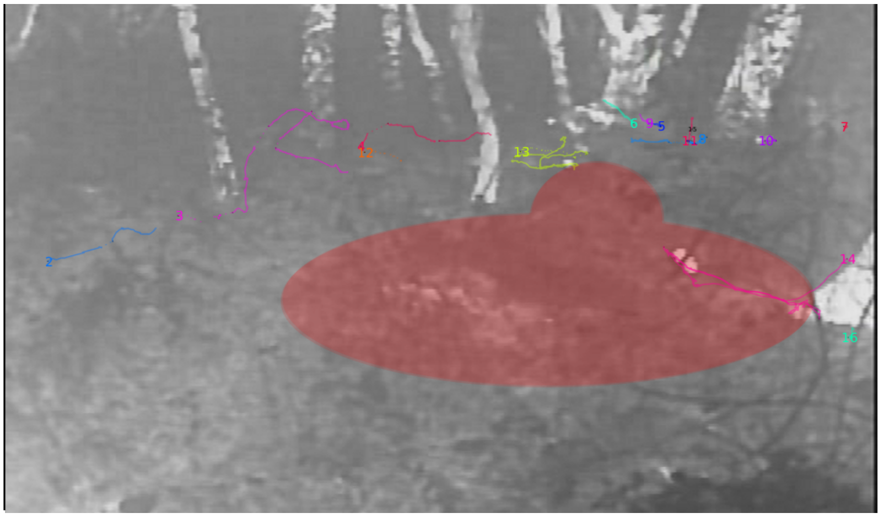

Figure 8: Positional tracking data overlaid over a still screen shot of the video.

Computer Processing Methods

Determining Nest Area in the Recorded Video

Landmarks and flags in the day-time photo are used to establish the nest area perimeter in the thermal video stream, see Figure 4.

Computer Vision

In general terms, endotherms create a moving bright blob in the thermal image. In our case these blobs are nocturnal mammals. We track the movement of endotherms in thermal video recordings using three basic steps:

1. Background subtraction and image clean up (Figure 5)
2. Blob detection and labeling (Figure 6)
3. Blob tracking (Figure 7)

We used the background subtraction capabilities of the computer vision library OpenCV (`http://opencv.willowgarage.com`) together with the object labeling and tracking functions in the library cvBlob (`http://cvblob.googlecode.com`) to identify moving objects and to record their positions and sizes. See `http://www.uncg.edu/mat/faculty/pauli/mouse/Applications-of-Object-Tracking-in-Video.pdf` for an overview of the methods used.

Track Processing

The tracking data are outputted as plain text, and then read into the track analysis program written in the computer algebra system Sage (`http://www.sagemath.org`). We reorganized the data into tracks and used their length, location, and direction as activity measures.

As we were specifically interested in mouse activity levels inside the immediate nest area, we modified the thermal video processing program to filter tracks based on their location relative to the nest site.

We determined activity levels within the 2m radius of the nest, activity outside the immediate nest area, and entrances into, and exits from, the immediate nest area. To exclude woodrats (*Neotoma macrotis luciana*) from our activity measures, we also watched portions of video from each focal nest to identify both woodrats and California mice at three distances from the thermal lens (near, mid-distance, and far). We took a screenshot of the thermal image and counted the pixels that made up the entire body of the mouse or rat (excluding the tail if it was visible in the image). We found that the lower bound on rat size did not overlap with the upper bound on mouse size.

We used this size information to filter out the tracks of any objects more than 1.2 times the size of the reference mice closest to the thermal lens. Furthermore, tracks of objects which did not move more than a minimal distance from their starting location were omitted from the analysis to reduce the influence of static erroneous foreground objects, such as the transient movement of foliage in the wind.

Results

The installation of a flag perimeter two meters around the believed nest site allows us to define discrete polygons in our video input streams. This simplifies scene geometry issues, and allows cameras to record video from a wider range of angles. Our object tracking python modules can now be used to gather data on the time mice spent near the nest, compared with the time mice spent away from the nest.

Discussion

The tracking methods work, and our field method measurements appear adequate despite the complicated terrain and vegetation of the field site. We are able to record mouse activity, and identify when tracks are or are not "near" the nest. This will work well for our study of mouse activity in relation to endocrine status of males.

Although data are only shown for one nest site, we have data for multiple nest sites. However, some sites will be easier than others to analyze based on the position of the nest and surrounding terrain.

We have yet to compare these computer generated data with telemetry and acoustic data. We expect that these will validate our computer methods.

One question to be considered is what the biological meaning of the two meter radius is to the mouse. Although we consider two meters "near" the nest, it may not be an accurate assumption. We should be able to use scaling methods to test this at some of our more simple nest sites.

Acknowledgments

The authors wish to thank the National Science Foundation (grants IOB-0641530, REU-0850465, DMS 0850465 and DBI 0926288 for Math Bio, and grants IOB 0641530 and IOB 1132419 for field work).

Thanks also go to the University of North Carolina Greensboro Office of Undergraduate Research, Dr. Jan Rychtar, Dr. Mary Crowe, David Schuchart, Caitlin Bailey, Christian Bankester and all the students who worked in the field collecting data, especially Tracy Burkhard. We would also like to thank the Hastings Natural History Reserve for all of their support of our field work.