Bringing the Field into the Lab: Large-Scale Visualization of Animal Movement Trajectories within a Virtual Island

Jillian Aurisano[*], James Hwang[†], Andrew Johnson[‡], Lance Long[§]
Electronic Visualization Laboratory
University of Illinois at Chicago

Margaret Crofoot[¶]
University of California, Davis

Tanya Berger-Wolf[‖]
University of Illinois, Chicago

ABSTRACT

Animal behavior research is becoming an increasingly data-driven field, enabled by advancements in GPS tracking. Rather than directly observe movement and behavior in small numbers of animals, over short time-spans and in small areas, researchers can use GPS collars to track many animals, over large areas and long time spans. These large datasets have the potential to provide rich information about animal behavior. However, this tracking data needs to be integrated with geospatial data about the environment in order to put the movements and estimated behaviors into context. We present an immersive visualization which integrates high resolution topological data from Barro Colorado Island, a 4000 acre island located in the Panama Canal, with GPS tracking data from close to two dozen primates captured over several months. Our application leverages parallelization for rapid filtering of the movement data, allowing researchers to explore the data in a large-scale, immersive environment (CAVE2). We present this work in order to explore the possibility of creating virtual field environments from data, to bring the field into the lab and enable big data animal behavior research.

Index Terms: Human-centered computing—Visualization—Visualization application domains —Scientific visualization

1 Introduction

While animal behavior research traditionally relied on data collection through direct observation in the field or in a laboratory setting, the development of approaches that utilize GPS tracking data presents new opportunities. First, tracking data permits researchers to simultaneously monitor many individuals at once, not just individuals within line of sight. In addition, tracking data permits researchers to capture movement across large areas, and areas that are difficult for humans to reach. Tracking data also enables researchers to record movements over long periods of time, and continuous stretches of time, providing valuable insight into behavior over long periods [7].

However, unlike observation-driven methods, where the researcher can directly incorporate rich information about the environment alongside the recorded behavior, GPS tracking data needs to be computationally integrated with data about the environment- terrain, topology and foliage- to put the data in an appropriate context for analysis. In addition, unlike observation-driven methods, tracking data can be quite large and noisy, requiring computational analysis approaches and data verification.

We present an immersive, large-scale visualization that integrates GPS tracking data from 26 mammals tracked over 30-90 days, visualized within a virtual 4000-acre tropical island, reconstructed from high-resolution terrain and tree-canopy topology data.

Our goal in displaying movement data in a virtual island is to help researchers address questions around foraging behaviors in different mammalian species. In particular, whether mammals with varied cognitive capacities are capable of using memory or their senses to locate and move toward fruit-bearing trees. Visual inspection of trajectories with respect to the canopy, from multiple points of view, could help address this question and aid in the design of computational approaches to measure differences between movement based on line of sight and movement based on memory [10]

Our application design targets two priorities: 1) the capability to view the data at human scale from many perspectives in an immersive environment and 2) the ability to rapidly select and move through subsets of the tracking data, isolating individuals and specific time frames, to view movement over time and movement with respect to one or many individuals. To meet these design goals, we designed our application within a large hybrid reality environment, CAVE2, used a custom point cloud library to represent the canopy, and leveraged parallelization on the GPU for rapid filtering of the movement data.

2 Related work

The value of GPS tracking data for studies in animal behavior and ecology is explored by Kays et al. [7]. We explore a new visualization approach to address some of the noted challenges with tracking data for studies of animal behavior.

The value of immersive environments, with head tracking and stereoscopic views, has been described both in the context of embodied cognition as well as for domain science applications [9]. Point cloud visualizations, particularly of LIDAR data, have been described extensively [8, 11]. Leveraging GPU parallelization in point cloud rendering, a technique we adapted in our application is described in Febretti et al. [5] and Hanula et al. [6].

There are many techniques to visualize spatial incident data and trajectories in 2d-representations [1, 2]. We depart from this body of work by looking at trajectories in immersive 3d.

3 Methodology

3.1 Environment

Our application was designed and deployed within the CAVE2, a hybrid-reality immersive environment consisting in a 72 MPixel stereoscopic display driven by a cluster of 36 16-core Xeon processor machines [4]. CAVE2 uses IR-reflective tracking to create user-centered perspective, and an IR-tracked wand for extended movement in the virtual space. The application was developed within a scalable application framework called OmegaLib [3].

3.2 Data transformation and visualization design

Our design is in three components: 1) creation of a virtual island from data, 2) visualization of tracked animal trajectories within the virtual island, 3) interactions to enable free movement through the island and rapid filtering of movement data, to allow researchers to select relevant individuals, and then step through time.

[*]e-mail: jauris2@uic.edu
[†]e-mail: Jameshwang2289@gmail.com
[‡]e-mail: ajohnson@uic.edu
[§]e-mail: llong4@uic.edu
[¶]e-mail: mccrofoot@ucdavis.edu
[‖]e-mail: tanyabw@uic.edu

IEEE LDAV 2019
21 October, Vancouver, BC, Canada
978-1-7281-2605-0/19/$31.00 ©2019 IEEE

Figure 1: An aerial view of the island with the point cloud canopy.

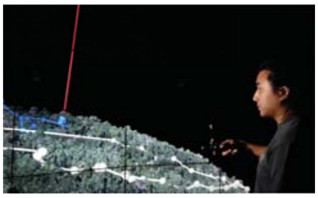

Figure 2: User examines movement data of a primate from an aerial position, viewing movement near the tree tops.

3.2.1 Creation of virtual island from data

Island canopy height was captured using depth from motion, captured during a drone fly-over of the island. We took the resulting height map, at 1 square meter resolution, and high resolution aerial image, at 18 cm squared per pixel resolution, to create a point cloud object (27 GB). We rendered each point as a sphere using a OmegaLib point cloud library, described in Febretti et al. [5], which allowed users to navigate with smooth updates to the view. An aerial view of the virtual island canopy point cloud is in Fig. 1. We generated a mesh for the ground, using height above sea level data. This height data was processed into a mesh using a custom script and we applied a texture with the high resolution aerial image using Blender.

The boundaries of fruit trees were identified using image processing based on the color of the foliage. To visually highlight the fruit trees, and assist in assessments of movement in foraging behavior, we placed a brightly-colored purple cylinder at the center of each identified fruit tree. The users could toggle the fruit tree cylinders on and off.

3.2.2 Animal tracking data

26 mammals from 4 species (spider monkeys, capuchin monkeys, coatis, and kinkajous) were tracked using GPS collars, over 30-90 days, with six signals recorded every four minutes. To enable analysis of trajectories, we adopted a visual design where each individual's recorded position was encoded visually as as spheres, connected by cylinders, within the canopy point cloud and terrain mesh. We provided the user options for coloring by individual identifier, to distinguish different tracked animals, or by time, on the scale of hours or days, with a gradient to denote the passage of time. We also determined that each displayed individual's start and end point needed to be labeled, along with the name of the tracked animal. This allows researchers to distinguish, relate and compare the movement of multiple individuals. This encoding can be seen in Fig. 2.

3.2.3 Interaction

The island could be explored using physical or virtual movement, using the IR-tracking system in CAVE2. Since the analysis tasks required rapid filtering and changes in color of the tracked data, we developed a custom geometry shader to control the display of the movement spheres and cylinders.

To efficiently pass data values for each sphere and cylinder to the GPU, we over-wrote data values in place of vertex color data, with the the day assigned to ”red”, the hour assigned to ”green”, the minute assigned to ”blue” and individual identifier assigned to ”alpha”. The geometry shader tested these color values against user settings passed into the shader, to determine whether to emit the primitives for the object and what color to apply.

A menu with options to select and filter the movement data, enabled users to select and toggle on/off different individuals and step through single day time steps, multiple days, or the entire time period. Since these selections were enacted through a custom geometry shader, the visualization updated with virtually no lag.

4 Results and Conclusions

Our application has been deployed and we observed coordinated movement in groups toward fruit trees, and situations where fruit trees are visible along movement trajectories from the animal's perspective. Future work will examine movement signatures associated with changing from normal movement to movement seeking a fruit tree which will inform the development of automated approaches.

Acknowledgments

The authors wish to thank Oliver San Juan, Ishta Bhagat, and Tyrone Harris for contributions to this project. This work was supported by a grant from NSF award 1456638.

References

[1] N. Adrienko and G. Adrienko. Spatial generalization and aggregation of massive movement data. *IEEE Transactions on visualization and computer graphics*, 17(2):205–219, 2010.

[2] J. Aurisano, M. Cha, and M. Snyder. User-driven predictive visual analytics on multivariate, spatio-temporal incident reports. In *Proc. IEEE VIS Workshop Vis. Predictive Anal*, 2014.

[3] A. Febretti, A. Nishimoto, V. Mateevitsi, L. Renambot, A. Johnson, and J. Leigh. Omegalib: A multi-view application framework for hybrid reality display environments. In *2014 IEEE Virtual Reality (VR)*, pp. 9–14. IEEE, 2014.

[4] A. Febretti, A. Nishimoto, T. Thigpen, J. Talandis, L. Long, J. Pirtle, T. Peterka, A. Verlo, M. Brown, D. Plepys, et al. Cave2: a hybrid reality environment for immersive simulation and information analysis. In *The Engineering Reality of Virtual Reality 2013*, vol. 8649, p. 864903. International Society for Optics and Photonics, 2013.

[5] A. Febretti, K. Richmond, P. Doran, and A. Johnson. Parallel processing and immersive visualization of sonar point clouds. In *2014 IEEE 4th Symposium on Large Data Analysis and Visualization (LDAV)*, pp. 111–112. IEEE, 2014.

[6] P. Hanula, K. Piekutowski, J. Aguilera, and G. E. Marai. Darksky halos: Use-based exploration of dark matter formation data in a hybrid immersive virtual environment. *Frontiers in Robotics and AI*, 6:11, 2019.

[7] R. Kays, M. C. Crofoot, W. Jetz, and M. Wikelski. Terrestrial animal tracking as an eye on life and planet. *Science*, 348(6240):aaa2478, 2015.

[8] O. Kreylos, G. W. Bawden, and L. H. Kellogg. Immersive visualization and analysis of lidar data. In *International Symposium on Visual Computing*, pp. 846–855. Springer, 2008.

[9] K. Reda, A. Febretti, A. Knoll, J. Aurisano, J. Leigh, A. Johnson, M. E. Papka, and M. Hereld. Visualizing large, heterogeneous data in hybrid-reality environments. *IEEE Computer Graphics and Applications*, 33(4):38–48, 2013.

[10] O. Spiegel and M. C. Crofoot. The feedback between where we go and what we knowinformation shapes movement, but movement also impacts information acquisition. *Current opinion in behavioral sciences*, 12:90–96, 2016.

[11] M. Wimmer and C. Scheiblauer. Instant points: fast rendering of unprocessed point clouds. In *Proceedings of the 3rd Eurographics/IEEE VGTC conference on Point-Based Graphics*, pp. 129–137. Eurographics Association, 2006.