Project Whirligig: Modeling the Swarming Behavior of Whirligig Beetles

Jared Haeme
Augustana College, Rock Island Illinois

Kyle McCaw
Augustana College, Rock Island Illinois

Tan Nguyen
Augustana College, Rock Island Illinois

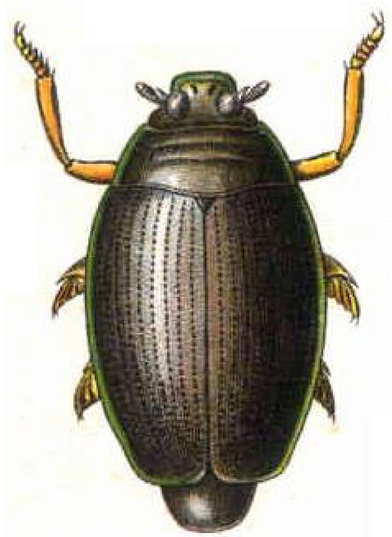
Tyler May
Augustana College, Rock Island Illinois

Project Whirligig: Modeling Swarming Behavior in Whirligig Beetles

Jared Haeme, Tyler May, Kyle McCaw, Tan Nguyen, & Forrest Stonedahl*

Mathematics and Computer Science Department, Augustana College *Faculty Advisor

I. Introduction



Whirlig Beetle
Family: Gyrinidae

This project was born of an interest by Dr. Forrest Stonedahl in modeling the swarming behavior of Whirligig Beetles he found and video-recorded along a path in Pigeon Creek Park in Bettendorf, Iowa. Our original plan was to use NetLogo to create a decently accurate simulation of these beetles, but upon further discussion, we realized that we may be able to simulate these beetles to a much greater degree of accuracy using actual observational data. We then set out to collect this data using computer vision, implemented using an open source library known as OpenCV, and deep machine learning, implemented using Google's TensorFlow library.

II. Methods

Using Computer Vision (OpenCV)

- OpenCV is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in commercial products.
- We initially used OpenCV to detect beetles in single frames through the usage of color masks, thresholding, corner detection, and more. Once we achieved a decent accuracy rate over single frames we moved onto multi-frame detection methods, as success with multiple frames is dependent on single-frame accuracy.

Using Deep Learning (TensorFlow/TensorBox)

- TensorFlow: Google's open-source machine learning library for numerical computation.
- Commonly used for deep neural network creation and research.
- TensorBox: A project for training neural networks to detect objects in images.
- We attempted to use deep learning methods to train a model to recognize beetles in each video frame. From there we aimed to teach the model to remember and track each beetle through multiple frames.

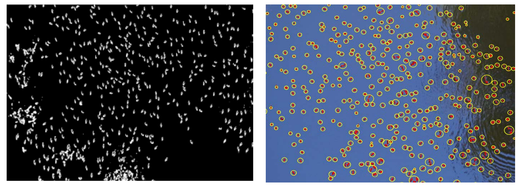
Using Agent-Based Model (NetLogo)

- Agent-based modeling is a computer modeling technique that focuses on modeling the rules of individuals ("agents") and simulating the interactions between these individuals.
- NetLogo is an agent-based modeling language and integrated modeling environment. It is a popular platform for building and running ABMs.
- We want to use NetLogo to simulate beetle movement using data collected from our videos.

III. Results

Computer Vision

- We were able to use single-frame detection methods, such as ***multiple color masks***, ***thresholding***, and ***corner detection*** to track the beetles in a frame with 96% accuracy for large-zoom videos and 90% accuracy for medium-zoom videos.

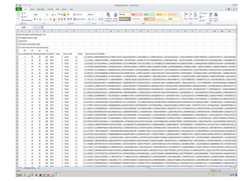


Thresholding *Corner Detection*

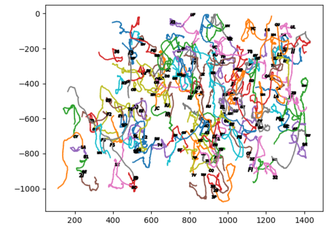
- By improving the accuracy of our single-frame detection methods, we were able to achieve 90% accuracy for our multi-frame tracking method.
- We also record the data of longest tracked beetles (those tracked for >200 frames).

Plot Beetles' Movements

- We exported all of the coordinates for the beetles to create a spreadsheet of the data. Then we used the OpenCSV library to read the CSV file and visualize the beetles' movement using graphs.



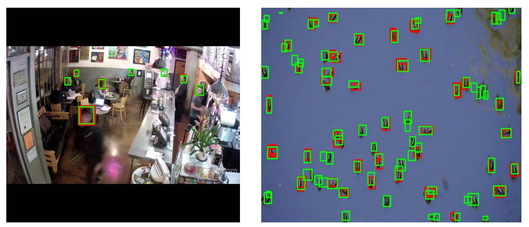
CSV coordinates file



Visualization of beetle movement (from multi-frame tracking)

Artificial Neural Networks

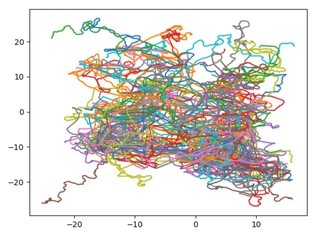
- We used TensorBox libraries on our hand-labeled images to train an artificial neural network model.
- After training, we achieved 84% accuracy of beetle detection on large-zoom videos using this machine learning model.



Face detection in TensorBox, modified to do beetle detection.

Agent-Based Simulation of Beetle Movement

- We also used data from the NetLogo simulation to plot the paths that simulated beetles took.



Visualization of beetle movement (from NetLogo simulation)

IV. Conclusion and Future Work

- We learned about a variety of different techniques for both manual and automatic object detection in images.
- Over the course of the research, we were able to continually improve single-frame detection algorithms from very low accuracy (less than 50% in some early attempts) up to 96% accuracy for large videos and 90% accuracy for medium videos.
- We used artificial neural networks (ANNs) to train the computer to track the beetles' movement. While ANNs were less accurate than our hand-coded algorithms, it could be a promising approach if large quantities of training data can be collected.
- We were able to use NetLogo to create an early prototype of a simulation for Whirligig beetle movements, and visually compare that data with the movement paths extracted from videos.
- **Future goals:**
  - Improve tracking of individual beetles between frames using more accurate beetle coordinates
  - Build a new agent-based simulation in NetLogo where motion is controlled by a data-trained neural network
  - Test how well these simulation results match the real beetle swarm behavior

V. References

- NetLogo (http://ccl.northwestern.edu/netlogo/)
- OpenCSV (http://opencsv.sourceforge.net/)
- OpenCV (https://opencv.org/)
- TensorBox (https://github.com/Russell91/TensorBox)
- TensorFlow (https://www.tensorflow.org/)

VI. Acknowledgements

- We would like to thank Dr. Forrest Stonedahl for allowing us to study under his direction during Summer 2017 and for his willingness to help us comprehend such a complex project.
- We would also like to thank the other summer research students from Augustana College and St. Ambrose University for their discussion and feedback about this work.
- Finally, we would like to thank the open source software community for making such a large set of sophisticated tools for image analysis and machine learning freely available.