Behavioral Classification of African Cichlids using Machine Learning

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ABSTRACT

Given time, all species have a particular ability to adapt to their habitats by changing their ecology and behavioral tendencies to survive in a fluctuating environment. This is the driving force for speciation and Africa's Lake Malawi serves as a prime model for investigating this process of adaptive radiation. However, many species do not share the same versatile morphology seen in cichlids, and rapid human-induced environmental changes have made it nearly impossible for many species to undergo the extensive speciation process that takes hundreds of thousands of years to be effective. In our project, we analyze the differences in cichlid behavior by developing a machine learning model that classifies behaviors using computer vision. Using DeepLabCut, a pose estimation model for animals, we are able to input new videos and retrieve coordinates for each cichlid body part, which in turn simplifies the process of data preprocessing for training a behavioral detection model by reducing the dimensionality of our training data. We can map each behavior to our species, helping us observe the finite and long-term effects that environmental changes have caused.

OUR GOAL

Researching cichlid speciation and classifying differences in their behavior will give insight into the effects of natural environmental changes in comparison to rapid human-induced changes that prevent speciation and cause **extinction.**

CICHLID EVOLUTION AND LAKE MALAWI HISTORY

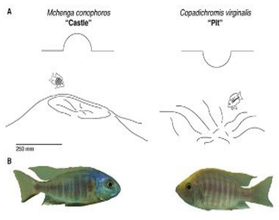


Figure 2: Basic Cichlid Bower Types [10]

- Lake Malawi is the most species-rich freshwater lake on Earth, home to an estimated 700–1,000 cichlid species that have rapidly evolved in the past 1–2 million years [2].
- Cichlid speciation was not a voluntary process, but rather, was a necessity for survival. In the last 1.3 million years, Lake Malawi alternated between "blue phases" (deep, clear water) and "green phases" (shallow, algae-filled water) caused by climate and tectonic shifts that coincide with timelines of cichlid diversification [1].

- The Lake Malawi Drilling Project extracted deep-water sediment undisturbed by bioturbation that show that the lake experienced 24 dry periods over that time, when lake levels dropped more than 200 m. After ~800,000 years ago, the lake was commonly deeper and overflowing, indicating wetter conditions These changes promoted the evolution of the endemic cichlid fishes, through shifting of habitats, and through isolation and restriction of populations [5].
- Fluctuating water levels created unique niches that induced natural selection on the population. Some niches include rocky shoreline habitats while others are described as flat and sandy. Fish in clearer water rely more heavily on visual cues for mating; therefore, the evolution of vibrant coloration and bower building became prevalent while behaviors in murky water are compensated with longer displays for courtship [9].

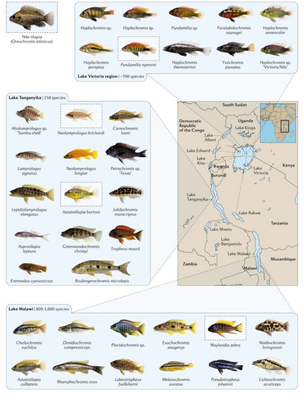


Figure 2: Cichlid Species in East Africa [8]

ENGINES OF INNOVATION

- More than 500 species of [cichlid] evolved within the past 10-15 thousand years–an eyeblink in geological terms–compared with the 14 finch species that evolved over several million years [7].

- How?
  - All cichlids have a normal pair of mouth jaws and a second pair of jaws located in the throat. Any food they eat gets grabbed and processed first by the mouth jaws and second by the throat jaws. As a result, cichlids can have mouth jaws adapted to one kind of food, and their throat jaws can break down other stuff [7].
  - The Cichlid Genome Consortium found that, in comparison to other fish, cichlids have:
    1. overabundance of proteins containing altered amino acids
    2. Higher mutation rates, especially seen in jaw development
    3. Rates of gene duplication that are up to five times higher
    4. Rapid accumulation of jumping genes
    5. Unique microRNA's that enables precision sculpting [11].

ACCELERATING EXTINCTION

- In the last two decades, decreased rainfall, deforestation, and improper siltation and sedimentation techniques of the huge lake has caused water levels to drop by an alarming sixty-percent. This trend can be seen across the entire planet, occurs in all ecosystems, and a continued decline in biodiversity will occur as species are unable to adapt quick enough to survive in habitats humans are constantly altering [3].
- Certainly, countless species have adapted to past climate fluctuations. However, their rate of change turns out to be painfully slow. Studies indicate that there is simply not enough time for species to change their morphologies – for example, by altering their bodies' shapes so they hold less heat – to compensate for rising heat levels. Too many generations of evolutionary change are required. Nor is moving habitat an option for many creatures [6].

POSE ESTIMATION WITH DEEPLABCUT

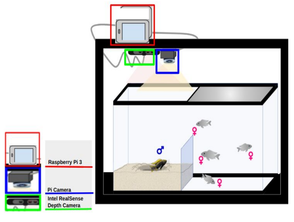


Figure 4: Experimental design

- DeepLabCut is a pre-trained multi-animal pose estimation model trained on mice, pups, marmosets, and fish. The model can identify animals, locate bod
- y parts specified by the user, as well as track the animal's movement. [4]
- With pose estimation, we can alleviate the issue of too much noise in our video dataset and develop a network that focuses on solely important parts of data, including cichlid location, movement, and interaction with other cichlids.

- The lab monitors 38 fish tanks with 4 female and 1 male cichlid per tank.
- Each tank is recorded from a top-down view.
- 4 annotators manually selected 50 frames per trial (tank) based on the number of cichlids in view.
- The DeepLabCut model trained on 1805 frames (95-5 train-test split), and we evaluated its predictions using mean euclidean distance.
- Currently, our lowest mean error is 6.75 px, which we aim to decrease by adjusting data manipulation, training hyperparameters, and cleaning up data.

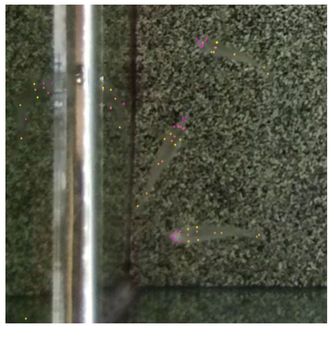
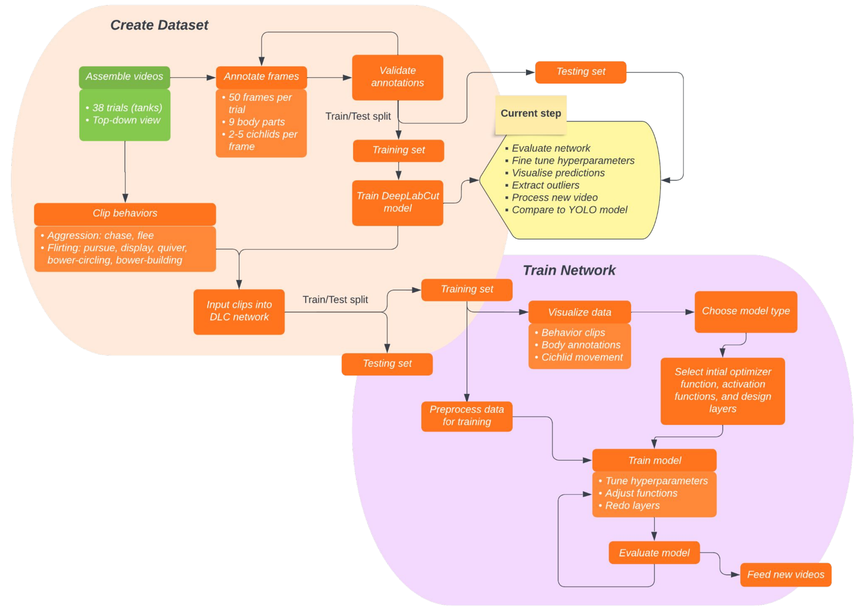


Figure 5: DeepLabCut detections (+) against manual annotations [4]



Lab Website

Jameson's LinkedIn

Michael's LinkedIn

DeepLabCut detections

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