Analyzing Lizard Movement with Hidden Markov Models

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Hidden Markov models (HMMs) are models for time series data in which the observations are the result of an underlying state process. HMMs are often used in an ecological context to classify animal movement behaviors. The aim of this project was to collect lizard movement data in a lab setting, then analyze and interpret it using HMMs in order to uncover patterns of distinct behaviors.

INTRODUCTION

- Hidden Markov models (HMMs) are time series models for observations that are driven by an underlying state process.
- HMMs are used in ecology for detecting patterns in animal movement data which indicate hidden behaviors.

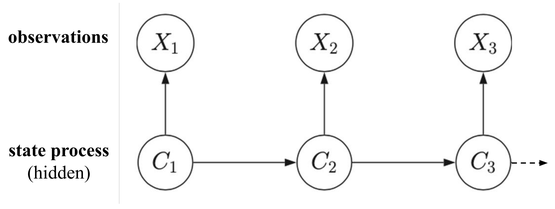

Figure 1: *The structure of a basic HMM with X_1, X_2, X_3 being the observations and C_1, C_2, C_3 being the hidden states.*

- The animal movement time series data can be decoded to reveal the most likely sequence of states that could have generated the observed movements.
- As a result, behavioral processes driving animal movements can be discovered using statistical modelling without the need for constant observation by ecologists.
- Lizard movement was collected and analyzed using HMMs in order to investigate these hidden behavioral states.

METHODS

The Setup

- Twelve lizards of the species *Podarcis muralis* were placed in a rectangular arena with a heat lamp at one end of the arena producing a thermal gradient.
- Each lizard had a 2-hour trial in the arena recorded by an overhead video camera as well as a thermal imaging camera.

Figure 2*: An image of the lizard in the arena. The red dot indicates the object being tracked by the software Tracktor.*

Data Extraction

- The body temperature of the lizards and the arena were extracted from the thermal images.
- The positions of the lizards in time was extracted from the videos using the free open-source software Tracktor.

R Package

- The *lizardHMM* R package was developed in order to fit the movement data with hidden Markov models.

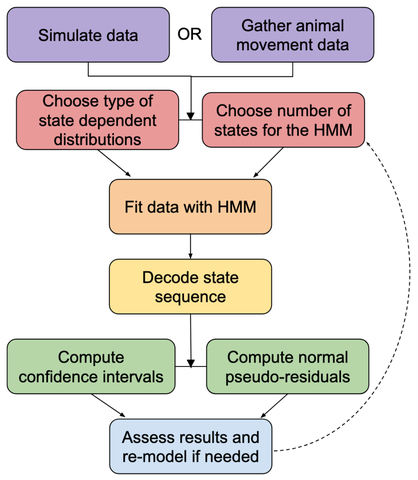

Figure 3: *Flow chart for the process of fitting an HMM to simulated or real data using the lizardHMM package.*

RESULTS

- One 2-hour time series of lizard displacement was log transformed and then fit with a two state HMM using the *lizardHMM* package.

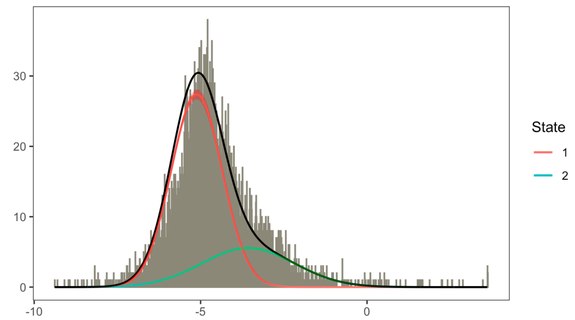

Figure 4*: A histogram of the log-transformed displacement per second of the lizard with the state dependent distributions and the marginal distribution overlayed.*

- The time series was decoded with small displacements assigned to state 1 and large displacement to state 2.

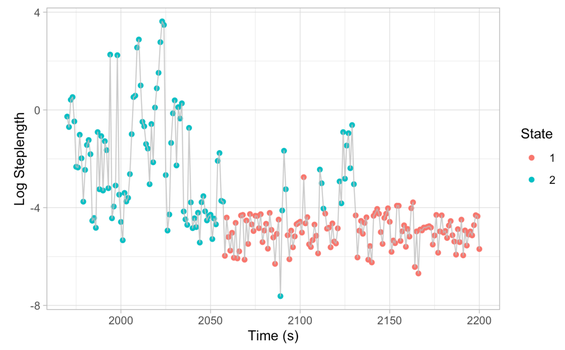

Figure 5*: A plot of the log-transformed displacement per second of the lizard versus time. The colors correspond to the decoded state sequences with red as state 1 and blue as state 2.*

- The video revealed that the state 1 (red) corresponds to when the lizard is at rest and state 2 (blue) corresponds to when the lizard is moving.
- This fitted HMM is likely to contain serval behaviors within each state but, increasing the number of states may not provide ecologically relevant behaviors.

DISCUSSION

- There is a lack of readily observable behaviors in the controlled lab environment.
- Going forward, the goal is to extend the basic HMM to include a feedback mechanism between the state process and temperature.

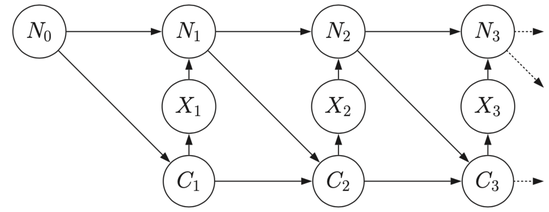

Figure 6*: An extension of the basic HMM in Figure 1 including N_0, N_1, … as a feedback mechanism. These feedback states have an influence over the state process C_t while simultaneously being affected by the observation process X_t.*

- Future work will provide more context on the relationship between lizards and their thermal environment, and the adaptability of these ectotherms to a changing climate.

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