MACHINE LEARNING METHODS FOR KINEMATIC ANALYSIS OF KANGAROO RAT HOPPING

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Introduction

Kangaroo rats are small bipedal hoppers that manoeuvre on variable and unpredictable terrain, which could make the animals lose their balance [1]. The tail of kangaroo rats has been assumed to play a key role in maintaining balance during hopping by counteracting the pitching of the body. The motion of the tail is controlled by tendons spanning from the base of the tail and attaching at each of the 26 vertebrae with four tendon groupings. Because of these >100 attachments, kangaroo rats have many options for controlling and moving their tail. We hypothesize that kangaroo rats use only a limited number of stereotyped shapes during hopping to reduce the redundancy of the tail structure.

Methods

Previously, we collected video of kangaroo rats hopping on a custom designed circular treadmill on which we can use different substrates and obstacles (e.g., sand and rocks) [1]. Analysis of hopping kinematics involves digitizing the video data to obtain the position of anatomical landmarks; in the past, this required manual labelling of each video frame, which is prone to errors and is inefficient for analyzing lengthy videos. DeepLabCut is an openly available software for markerless pose estimation utilizing neural networks that can digitize videos quickly [2]. We trained a ResNet neural network inside DeepLabCut to track markers on the tail, legs, and body.

A previous study used principal component analysis (PCA) to reduce the dimensionality of movements during jumping in humans [3]. Our aim is to apply PCA to the shapes of kangaroo rat tails recorded during the hop cycle to determine whether a limited number of tail shapes are needed to explain the variability of shapes during the hopping cycle. The analysis plan consists of: (1) Marker position data from each frame are exported from DeepLabCut and the tail markers are fitted to a spline using MATLAB; (2) The splines, and body points, are then used to build a prediction model using neural networks to classify each frame of videos as a percent of the hopping cycle (1 to 100%). This allows us to apply PCA to the tail shapes at specific phases in the hop cycle and across kangaroo rats.

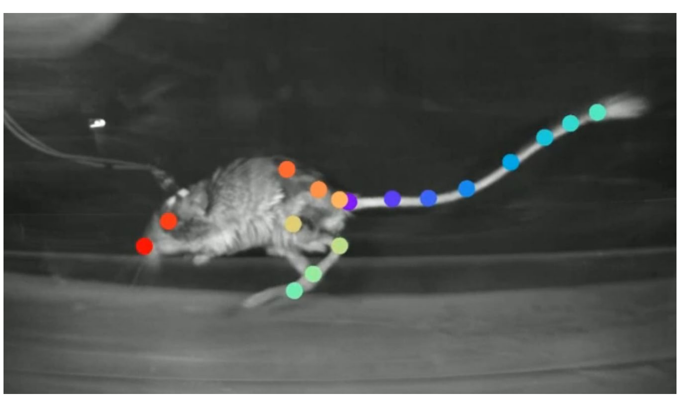

Figure 1: Screenshot from a video generated using DeepLabCut. Predicted locations of various body parts are superimposed on top of the inputted video.

Results and Discussion

The trained network was able to track the markers on the body and tail on our most clear videos (Fig. 1). We are currently experimenting with preprocessing techniques to assess the ability of DeepLabCut to digitize less-clear videos. Splines were fitted to the tail data for each frame (Fig. 2). Currently, we are in the process of constructing the prediction model for tail motion throughout the hop cycle, after which we can apply PCA to determine the variance accounted for each principal component.

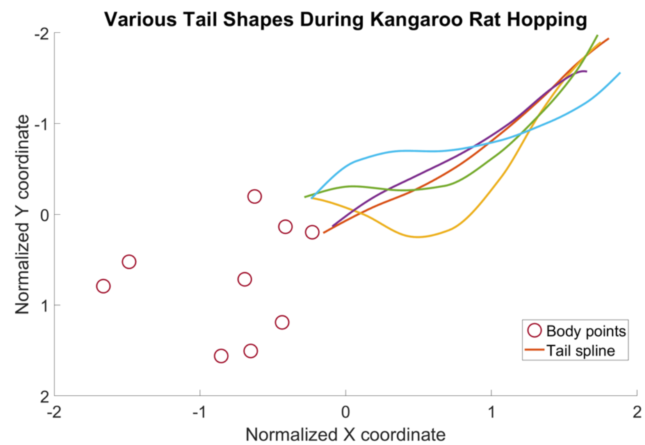

Figure 2: Splines fitted to tail marker data for each frame during a hop cycle (5 frames shown). One frame of body position is shown too.

Significance

Recent advancements in neural network research and the increasing accessibility of computing power have expanded the capabilities of neural networks. DeepLabCut is an example, where a tedious process can be automated once a neural network is trained properly. Building a framework to analyze large amounts of video data will help our lab analyze video data much more rapidly than previous manual digitization. Neural networks also rely on large amounts of data to make accurate predictions, and videos with high frame rate are rich for using neural networks in kinematic analysis.

Understanding how kangaroo rats utilize their tail in their gait cycle can be insightful for understanding how these animals are able to hop on variable and unpredictable terrain. Ultimately, we wish to confirm the long-standing assumption that kangaroo rats use their tail to compensate for unwanted forward and backward pitch of their body during hopping. Also, understanding the common shapes of the tail will enable better understanding how the extreme redundancy of the tail is controlled.

Acknowledgments

Funding provided by the Army Research Office (66554-EG) and National Science Foundation (1553550).

References

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