KineMouse Wheel: A standardized turn-key open-source behavioral tracking system for head-fixed rodents

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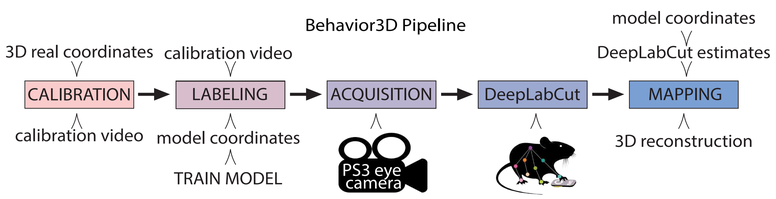
1 Abstract/Introduction

- Current methodologies for quantifying 3D behavior of head- fixed mice are limited by expense and invasiveness, lack of access to bottom view of mouse, and do not present a reliable system for calibrating cameras.

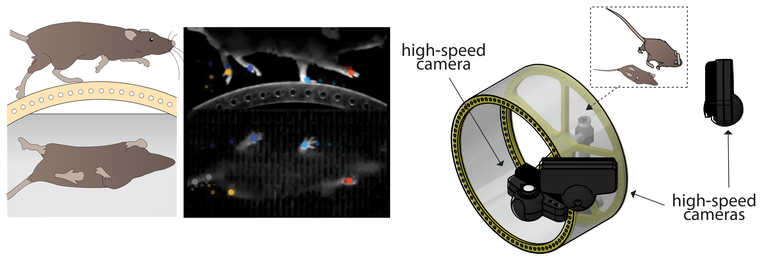
- The proposed framework achieves end-to-end behavioral analysis through a setup composed of lightweight, transparent treadmill, acquisition software for low-cost high-speed cameras arranged to access multiple perspectives on the body, a computational method to map movements with single digit precision in 3D space, and analysis to infer patterns from data.

- Usage is demonstrated in example settings.

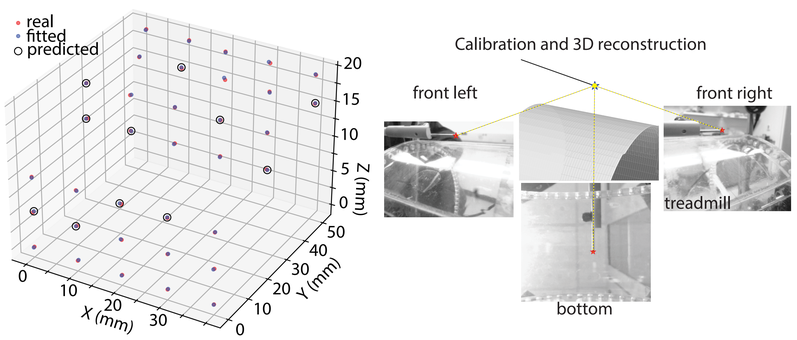
2 Methods



Pseyepy software allows simultaneous recordings of KineMouse Wheel to be made and saved in numpy arrays, operate at ~70 Hz@640x480 on up for four cameras and ~180 =Hz@320x240 on up to five cameras.

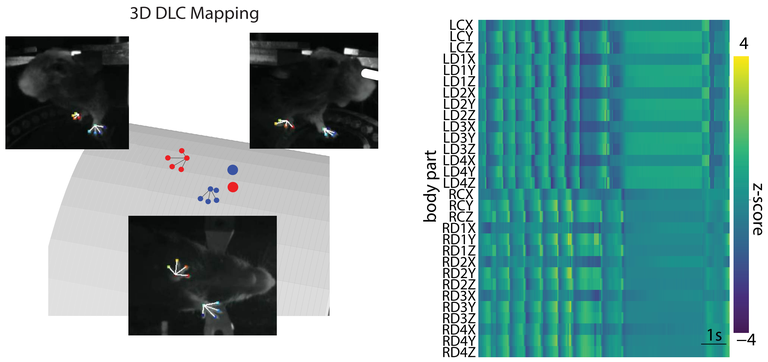


3 Results: Calibration

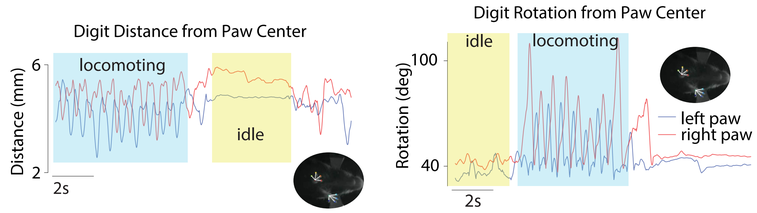


A function $f(x_1, y_1, x_2, y_2, \ldots, x_n, y_n) = (x,y,z)$ defined by training machine learning algorithm (SVR), where (x, y, z) are coordinates for known location in space, and (x_n, y_n) are extracted by each camera. $R^2 = 0.998$, RMSE= 0.1273 mm.

4 Results: Mapping

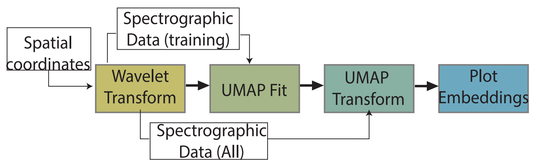


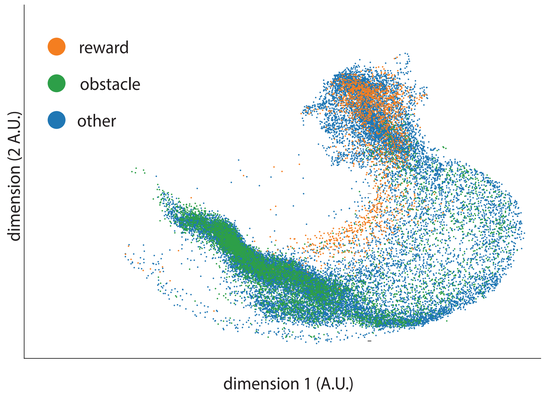
DLC data from multiple cameras is combined with the mapping model, f(), to reconstruct body parts in 3D. Visual inspection of 3D projection and heatmap of body parts confirm accurate 3D reconstruction.



The setup is able to track fine scale movement. Figures demonstrate expected oscillations following stance and swing phases of locomotion and differing levels of paw rotation.

5 Results: Behavior Analysis with UMouse





Further visualizations allow for embeddings coded for various running speeds and interactive plotting features that displays positional traces over time for chosen data points.

6 Conclusion

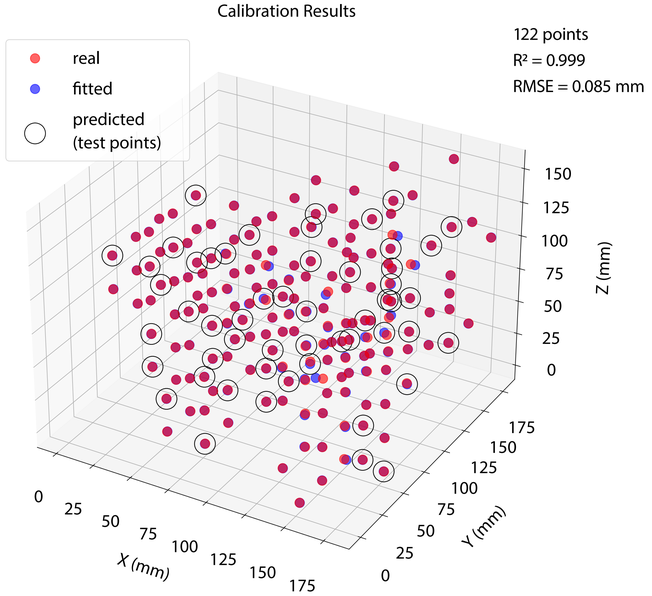
- An end-to-end pipeline for behavioral analysis is proposed that implements all the necessary steps to inspect the behavior of a head-fixed animal from construction of a wheel and data acquisition, to the visualization of low-dimensional behavioral attributes using UMouse.

- This framework provides users a reliable, inexpensive and simple way to analyze behavior at high resolutions.

-Implications of this work include linking these fine behavioral features with neurophysiological recordings to better understand the neural basis of locomotion.[1] Additionally, screening of motor function defects in mouse models of disease could be carried out with better precision.[2]

In Progress/ Future Work

Software:
- Updated automatic calibration script. 8x8x8 LED calibration cube filmed by camera set up, python code automatically extracts LED points in 2D to map to 3D.
- Incorporation of DeepLabCut thresholds for predictions/confidence intervals in machine learning algorithm to improve reconstruction results.



Hardware:
- Updates to KineMouse Wheel to encourage mouse locomotion: barriers to enclose in space, periodically rotating stepper motor.

References

1. Sofroniew NJ, et al. Elife. 2016
2. Machado AS, et al. Elife. 2015