Using Deep Learning for Mouse Pose Estimation and Motion Analysis in 3D

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Background

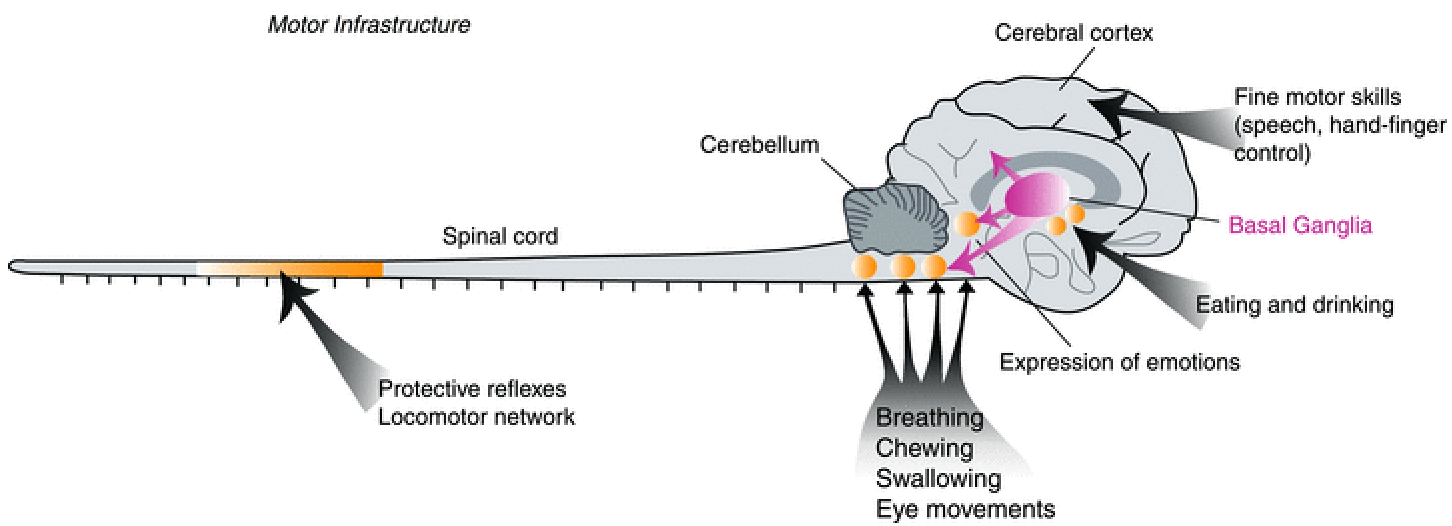
Main Objective

To understand the neural basis for jumping in mice.

- Core behavior used in many contexts
- How do different neural cell types contribute to the way a mouse jumps?

Neurology of Jumping

- Locomotor networks in the brain and spinal cord
- Manipulating locomotor network can affect movement
- How can we see if the jump has changed?

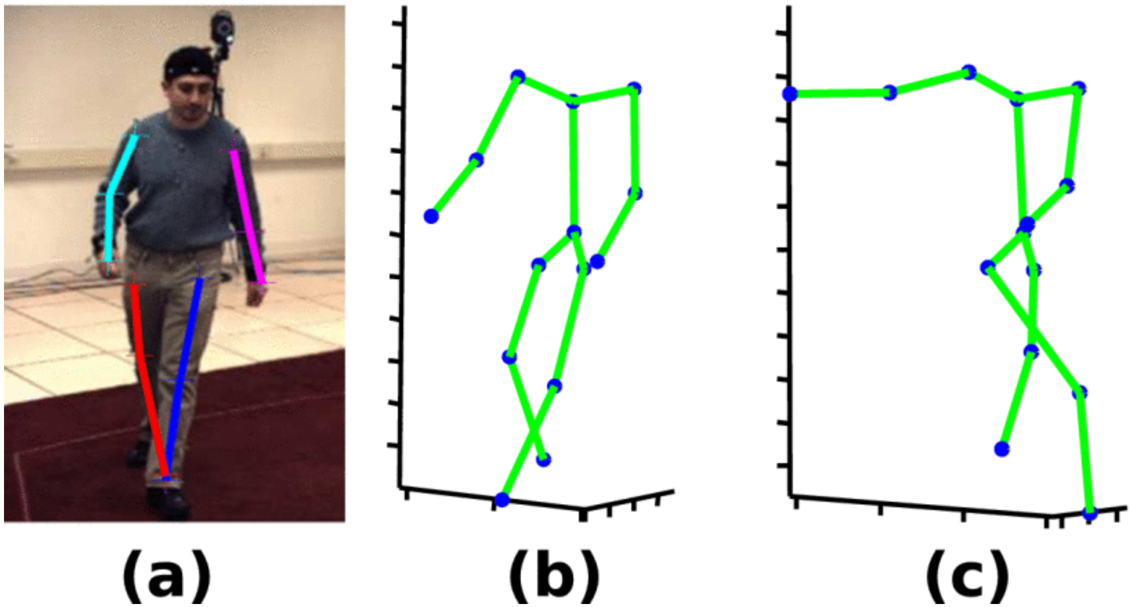


Grillner et al., 2013

Pose Estimation

Pose Estimation

- Must quantify movement in order to analyze
- *Articulated body pose estimation*: automatically detect a body's pose in an image
- Complex but central problem in computer vision



Wang et al., 2019

Deep Learning

- Machine learning algorithms modeled after human brain to “learn” information
- Two phases: training and analysis
- Training: critical process of learning parameters
- Analysis: apply trained network to new data
- Many applications, including *pose estimation*

DeepLabCut

- Public deep learning software for animal pose estimation
- Uses a pre-trained Residual Network (ResNet) to analyze videos and identify user-specified joints
- Basis for our quantification of mouse jumping behavior

Nath et al., 2019

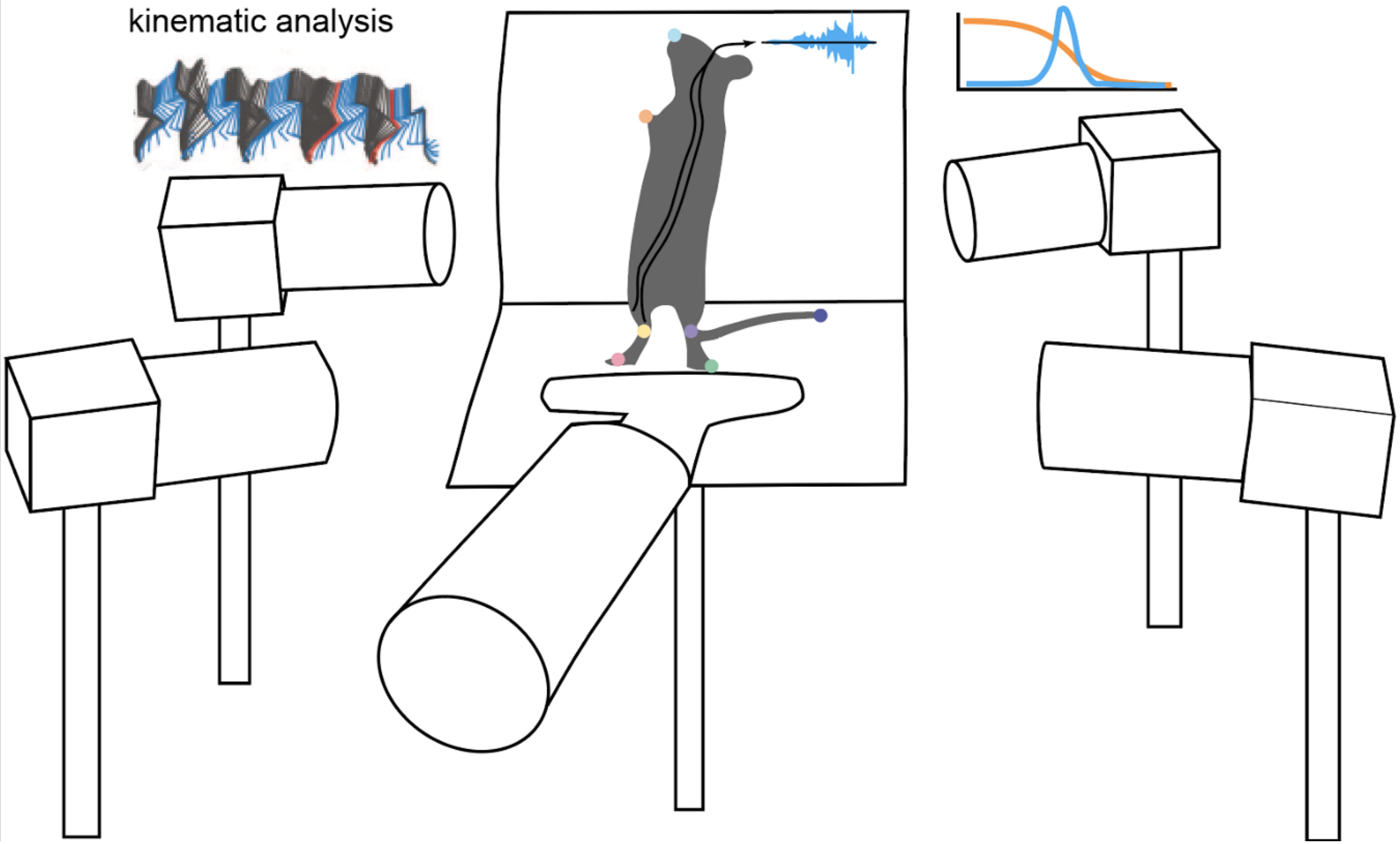
Experimental Methods

Apparatus

Video Cameras:
High speed capture for **body position** and 3D kinematic analysis

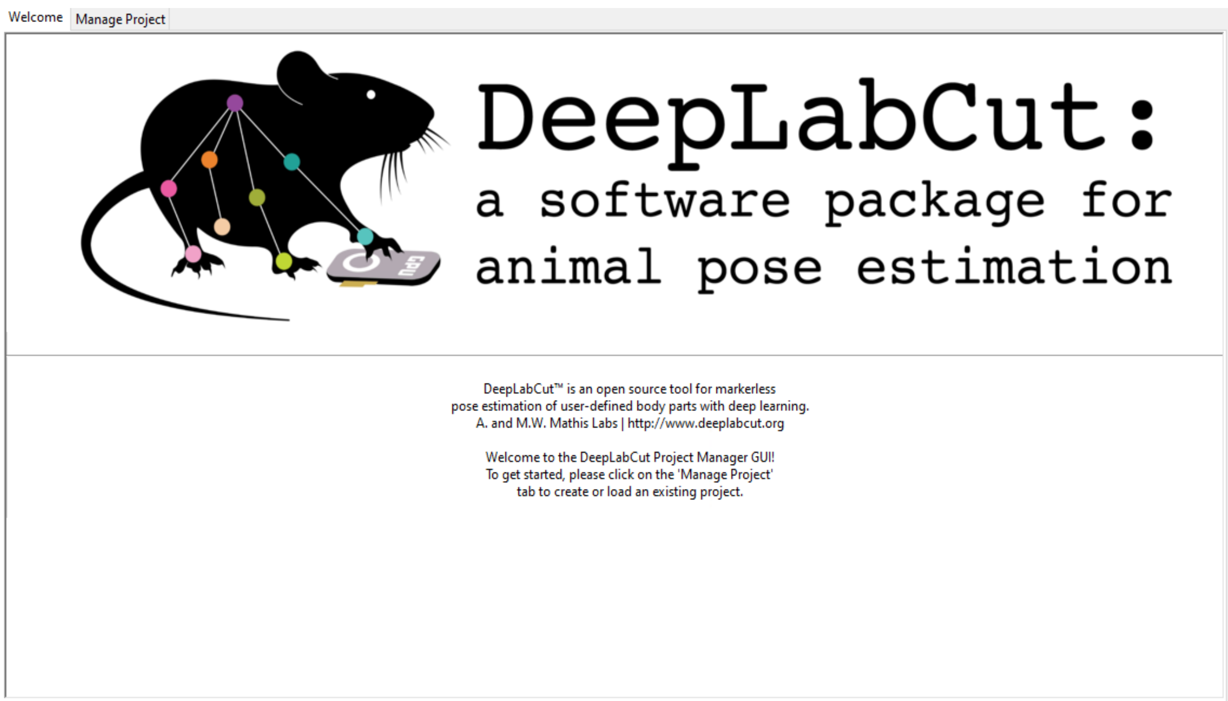
EMG Implant:
Muscle activity during behavior

Platform Sensors:
Force and platform movement



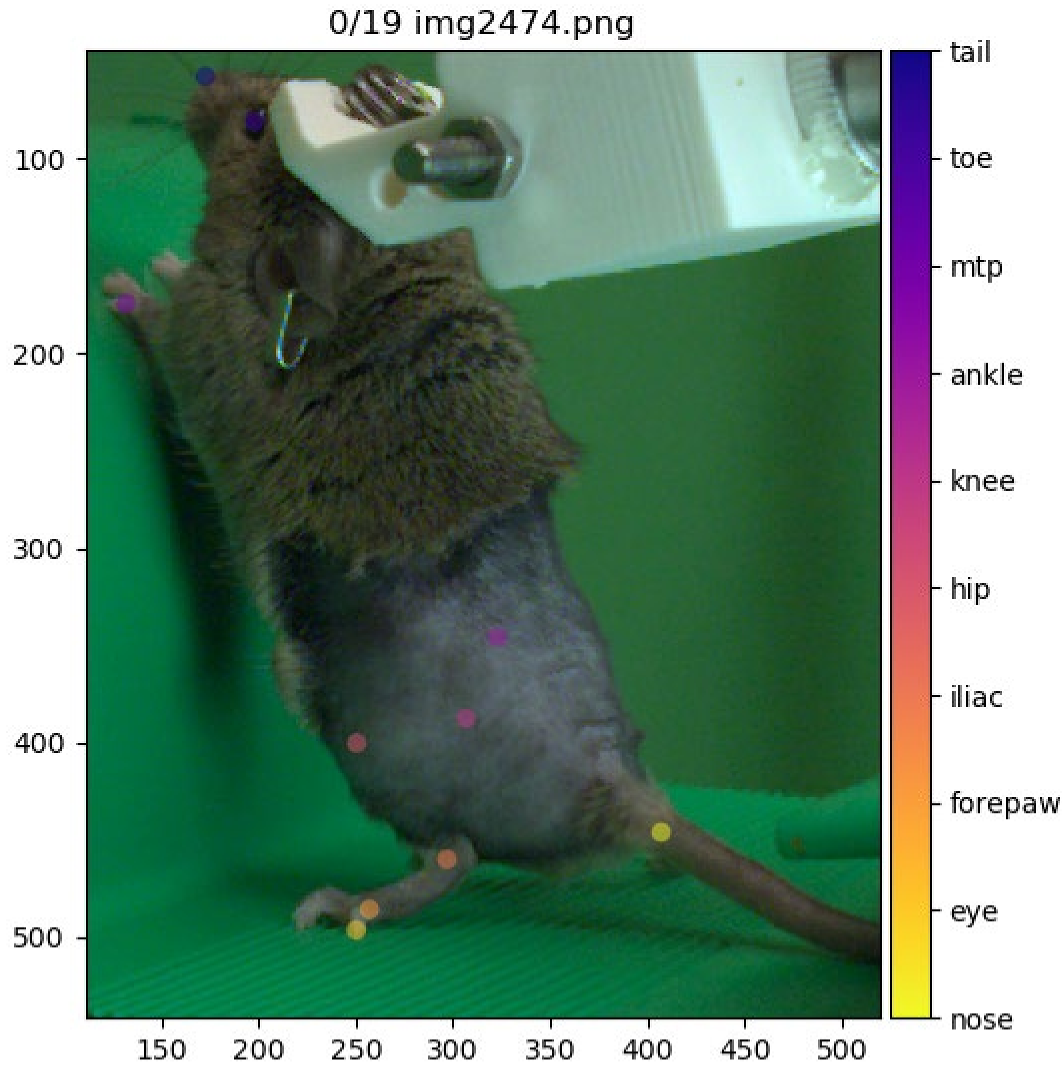
Software Environment

- Python 3.7 via Anaconda
- Graphics Processing Unit (GPU) and driver
- DeepLabCut (DLC) software and user interface



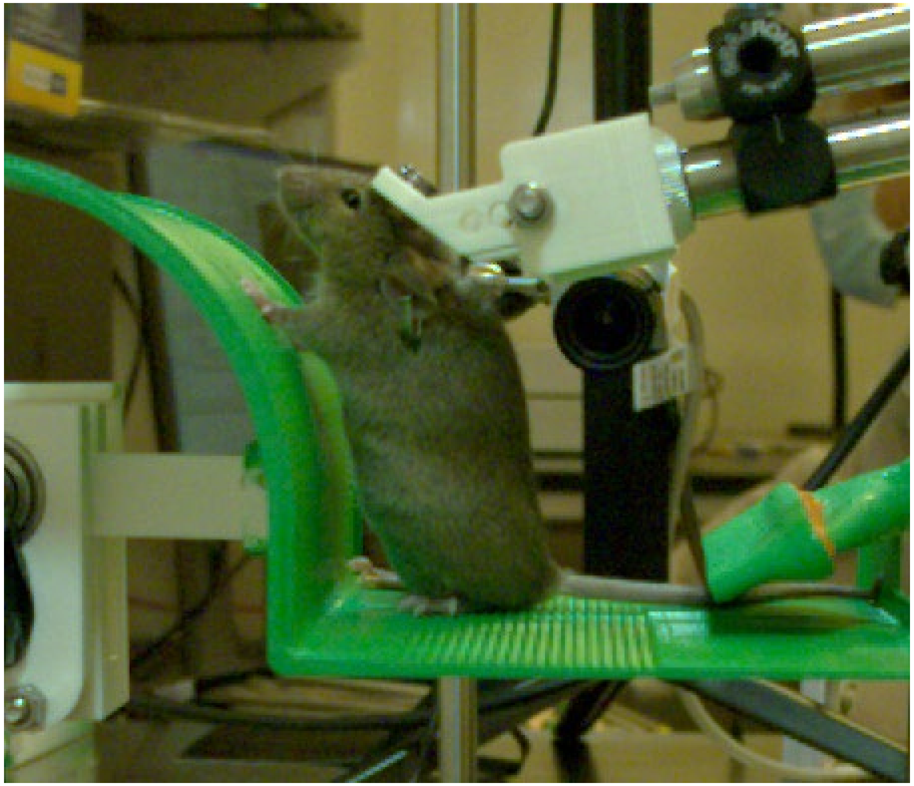
Body Part Labels

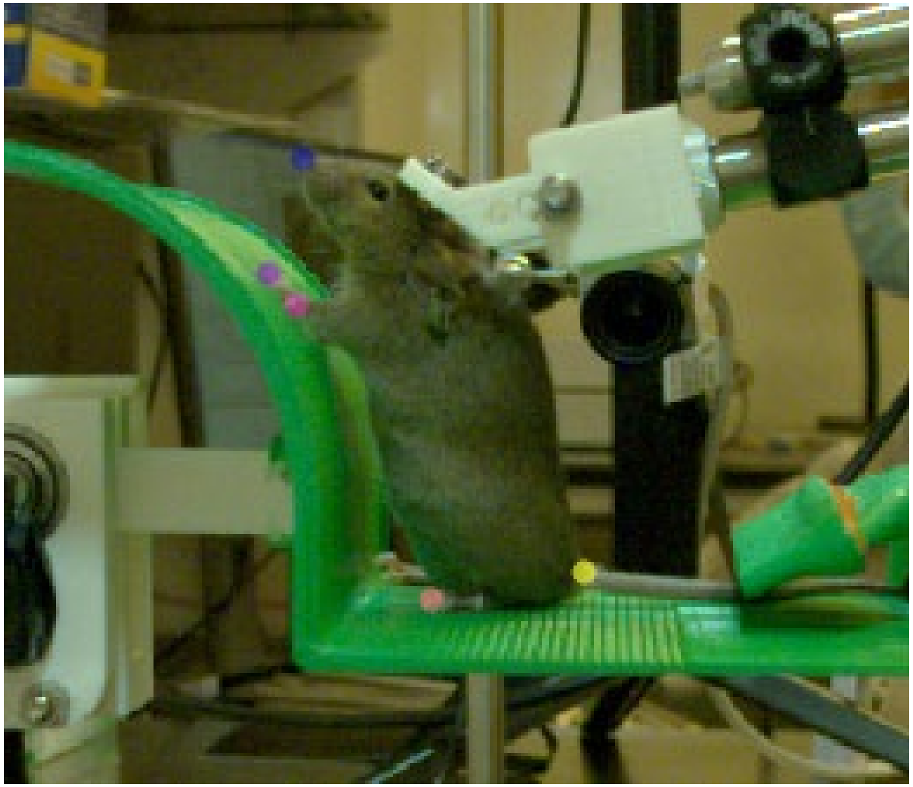
- DLC is designed for general use – requires user input
- For jumping behavior:
  - Nose, eye, forepaw, iliac crest, hip, knee, ankle, MTP, toe, tail base



Data and Results

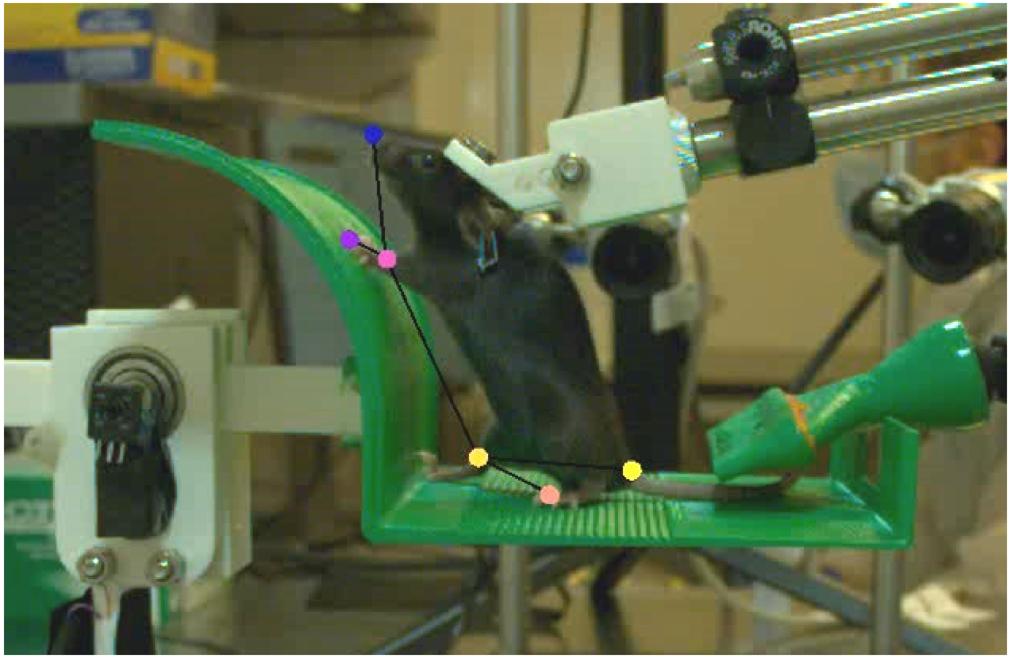
Proof of Concept – Data





Proof of Concept – Results

- Promising, clear indication that DLC is learning
- **Issues: limb switching, low resolution, motion blur, noisy and dark image, inconsistent data**

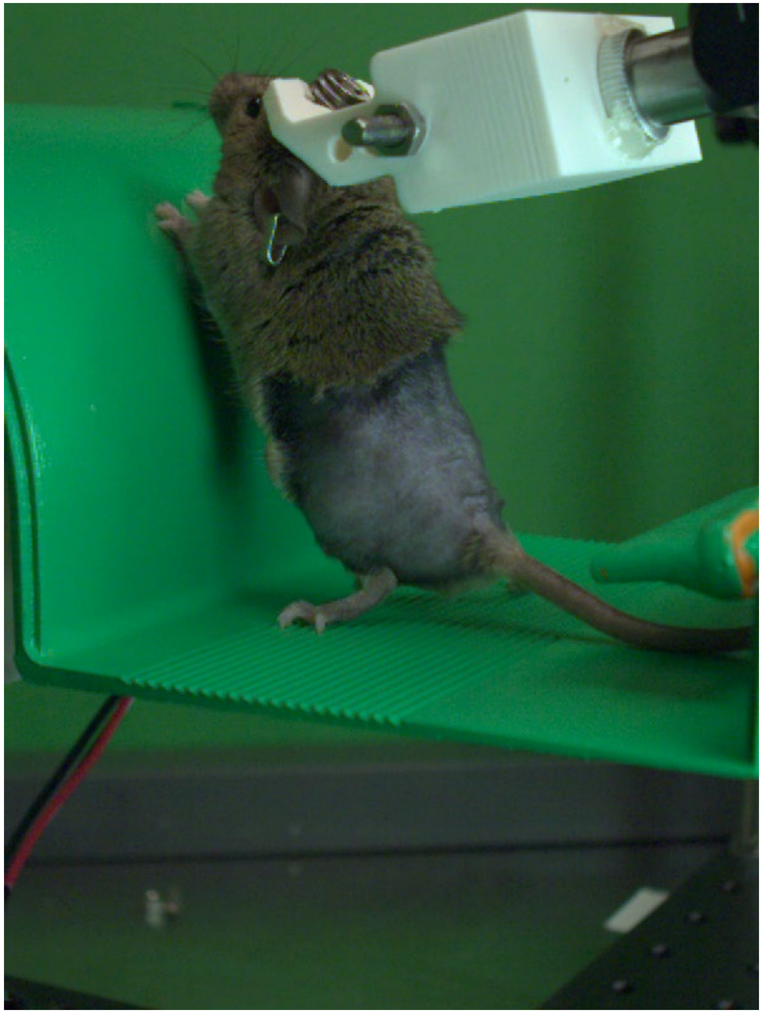


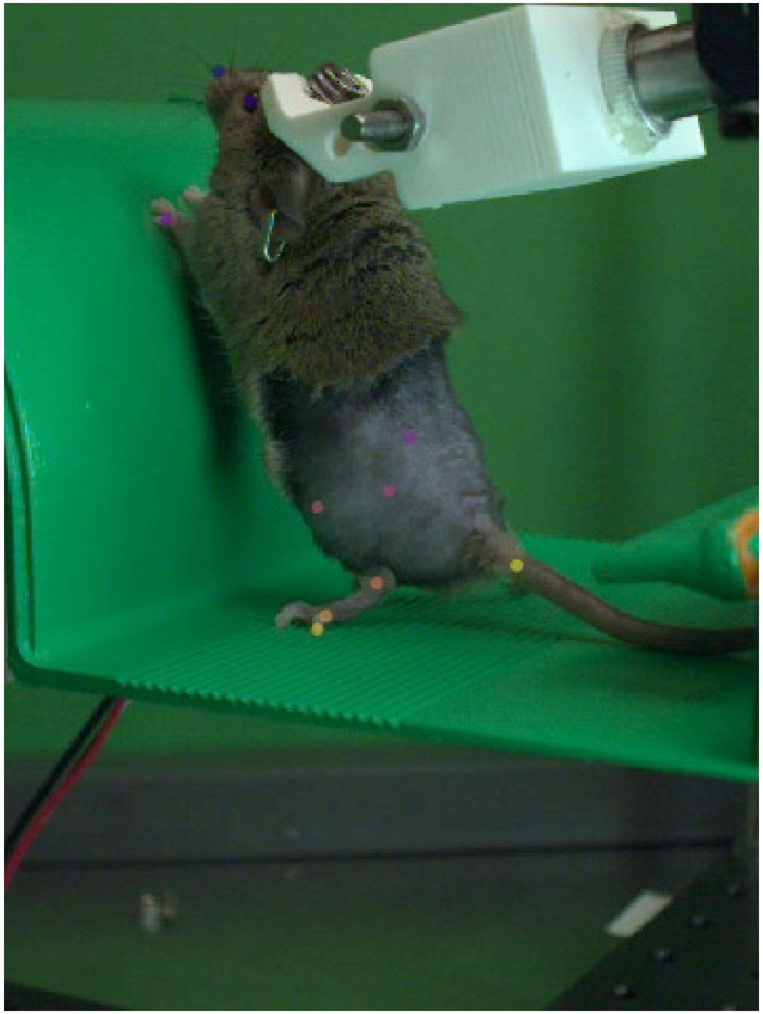
Design Adjustments

Issues: limb switching, low resolution, motion blur, noisy and dark image, inconsistent data

- Add more points
- Move camera closer
- Better lighting
- Increase video frame rate
- Shave mice, use same-colored mice
- Trim videos

Improved Data





Improved Results

- Adjustments proved highly effective at addressing issues
- Data is easier to label and analyze, with more consistent and accurate results

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Additional Analysis – Training Efficacy

- Validation: train error = 0.8, test error = 1.57 (in pixels)

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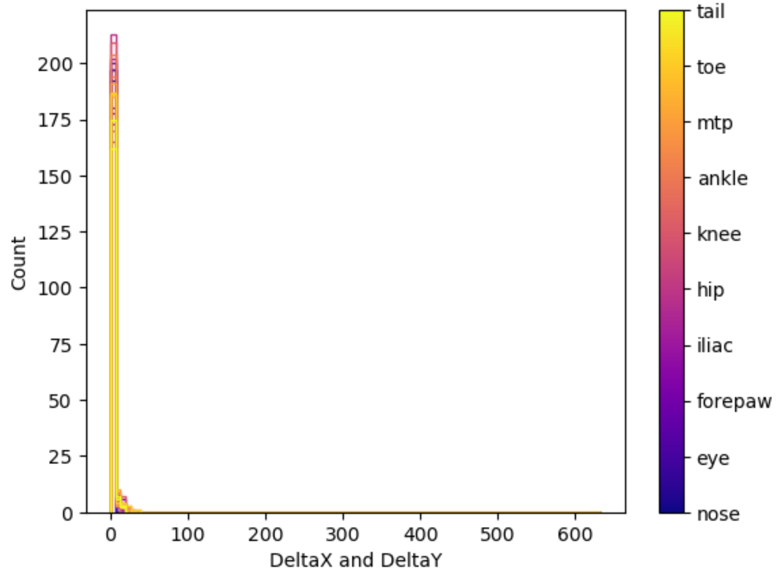
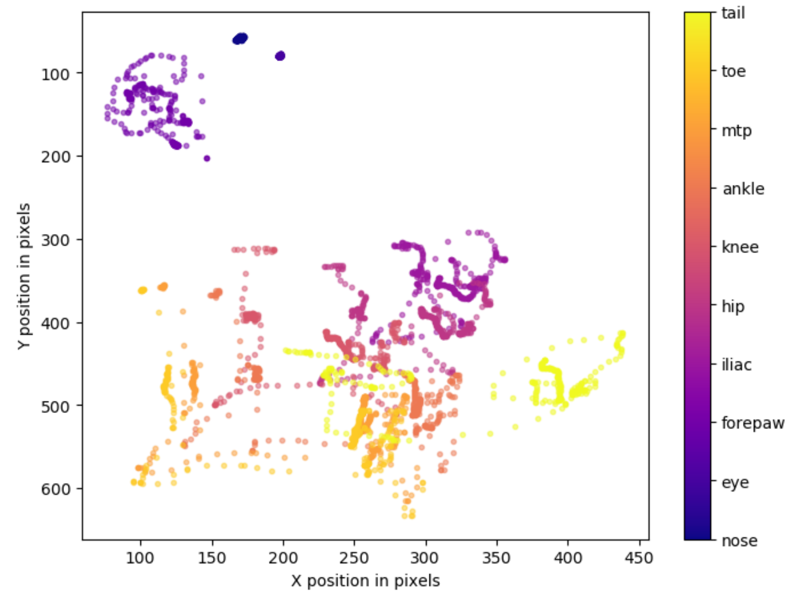
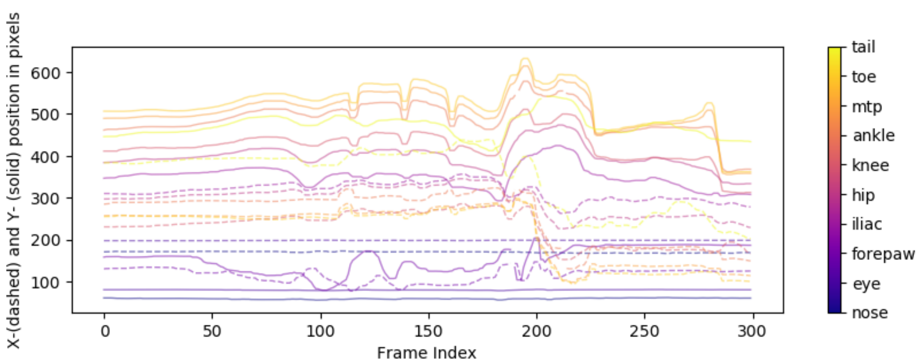
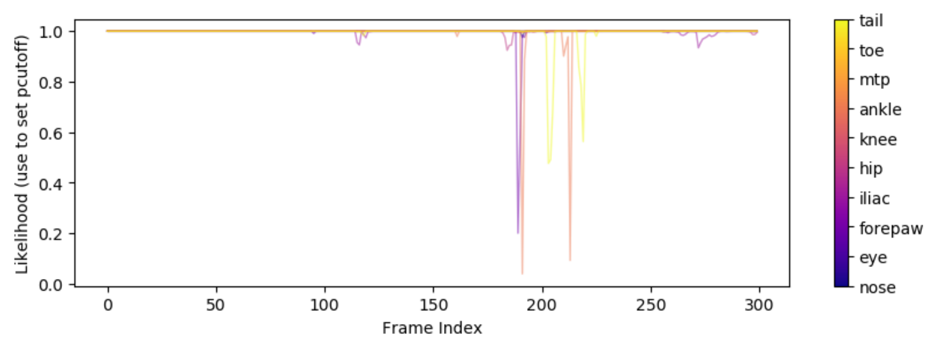
Additional Analysis – Generated Plots









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Future Directions

Future Directions

- Refine the training parameters in DLC
- Generate four DLC models for four camera angles
- Collect more data and analyze from all angles
- Calibrate across multiple cameras to obtain 3D position
- Synchronize with EMG and platform data

- *Perturb cell populations and quantify changes in jump*

Acknowledgements

A big, special thank you to Randy Pursley, Ghadi Salem, Krystal Santiago-Colon, Fabricio Do Couta Nicola, and Isabelle Hua, as well as everyone in the Spinal Circuits and Plasticity Unit and the Signal Processing and Instrumentation Section, for giving me the incredible opportunity to work on this project.

Also, a huge thank you to Robert Lutz and everyone at the Biomedical Engineering Summer Internship Program for making this internship happen, even in the face of extraordinarily challenging circumstances.

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Questions? Feel free to email me at tara.m.tang@gmail.com!