Computational NeuroEthology

Computational tools for studying behavior

Albert Einstein College of Medicine

Class 3
October 20th, 2025

Mikhail Kislin
Roland Ferger

Overview

- How to get from video to posture
- Posture dynamics ≈ Behavioral language
- Best Practices and Advanced Topics

01 Why Behavior Quantification Matters?

• Behavior is the brain's ultimate output understanding neural circuits requires equally precise descriptions of what animals actually do.

• Neural recordings are high-resolution; behavioral measures must match this precision to interpret neural dynamics.

• Modern tools allow continuous, high-dimensional tracking of posture, movement, and interaction.

•Traditional assays (e.g., lever presses, time in zone, binary scores) capture only a tiny fraction of ongoing complexity.

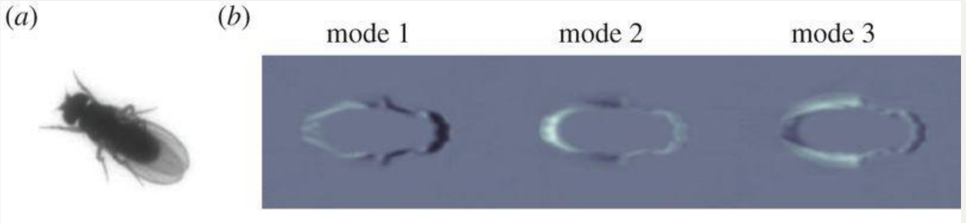
• Quantitative behavior should provide:
- objective, reproducible metrics
- access to latent behavioral states and motifs
- new ways to link circuit activity

behavior must be captured as a structured and quantifiable signal

Representations of animal to quantify distinct behaviors

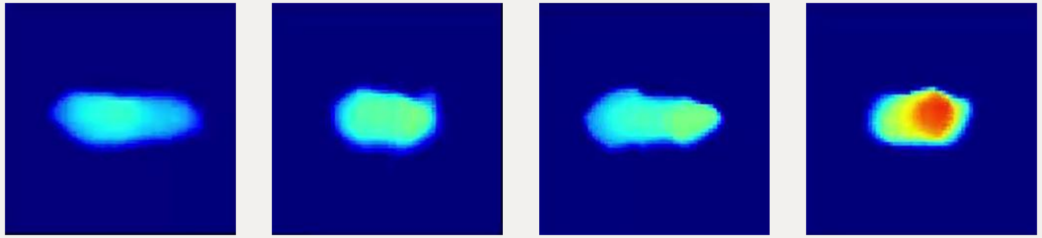
I) Model free

variance cross grey scale images



Berman et al. J.R.Soc.Interface 2014

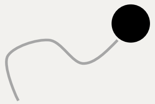
variance cross depth images



Wiltschko et al. Neuron 2015

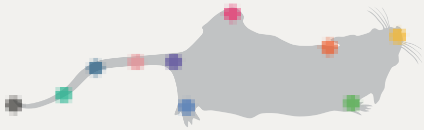
II) Model based

Coarse

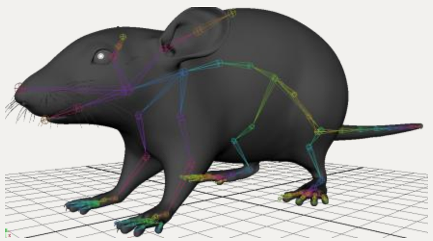


Centroid tracking

Ellipse tracking



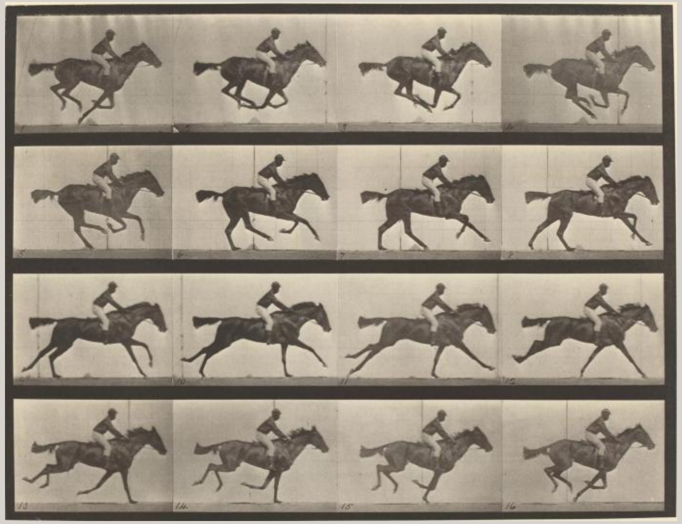
Single – animal pose estimation



Anatomically constrained 3d model

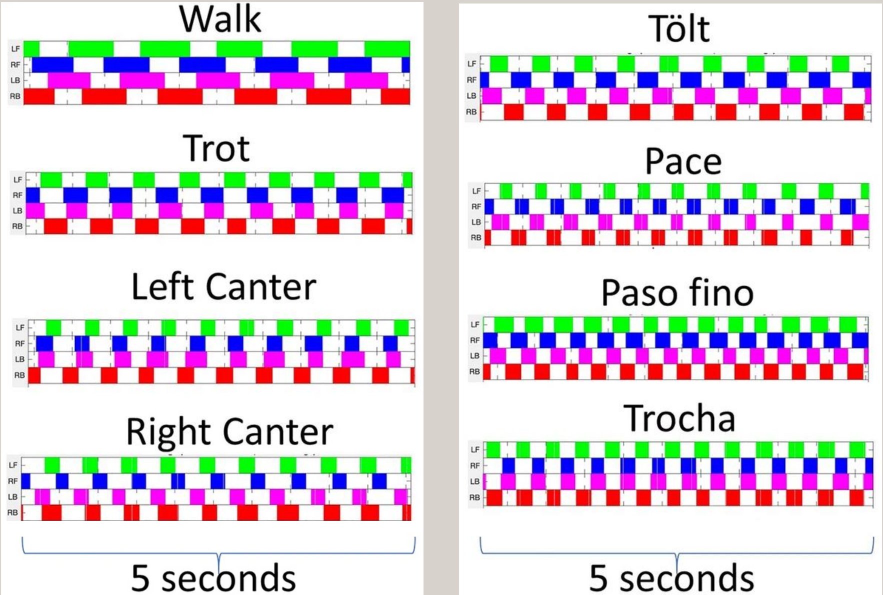
Fine

02 Biological motion capture



"The Horse in Motion" ,1878
Eadweard Muybridge

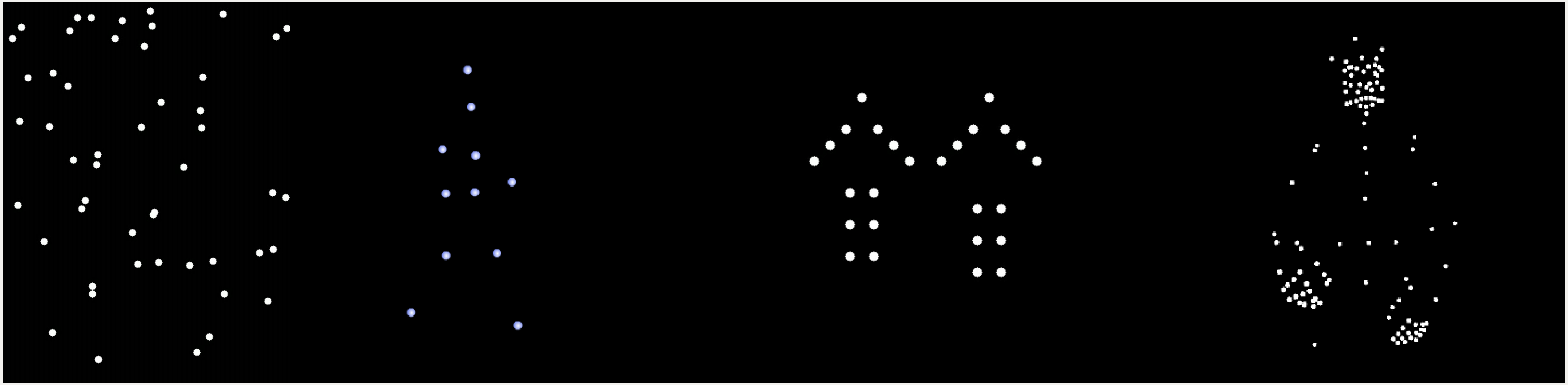
Footfall pattern of each different gait



White: swing phase; color: stance phase

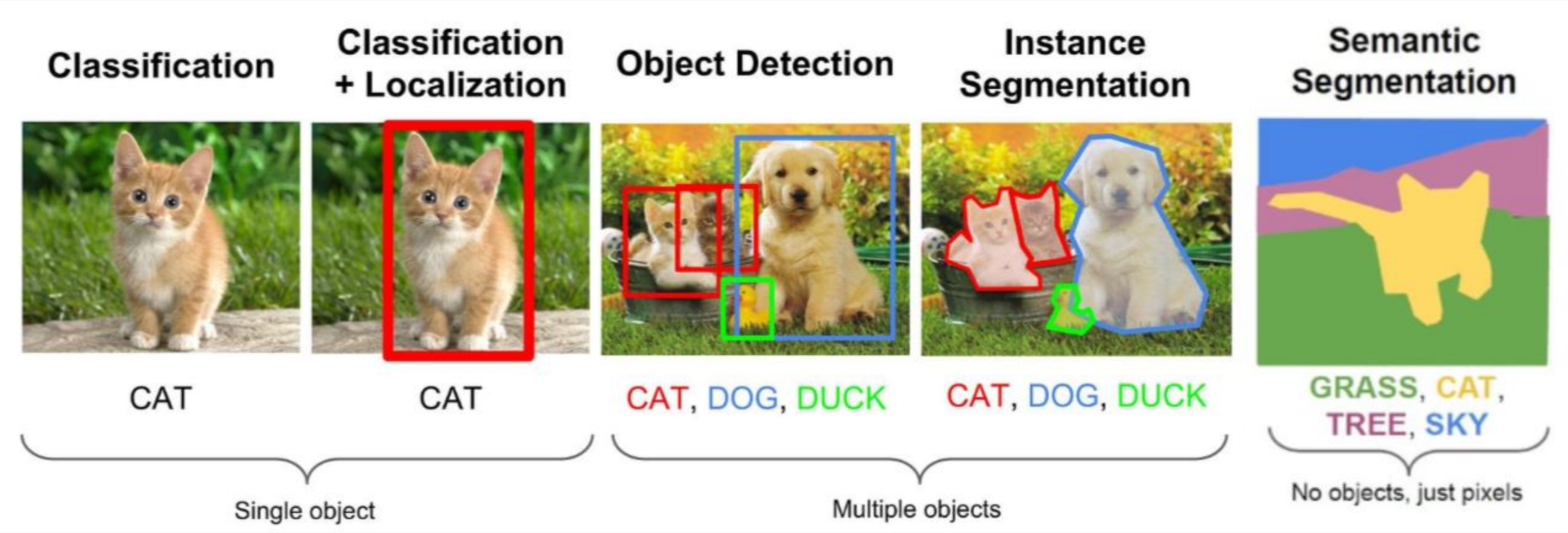
Biological motion perception

Gunnar Johansson experiments



Computer Vision: Techniques and Algorithm

enables computers to "see" and interpret visual information from images and videos like humans do



Deep learning methods for animal pose estimation

DeepLabCut:

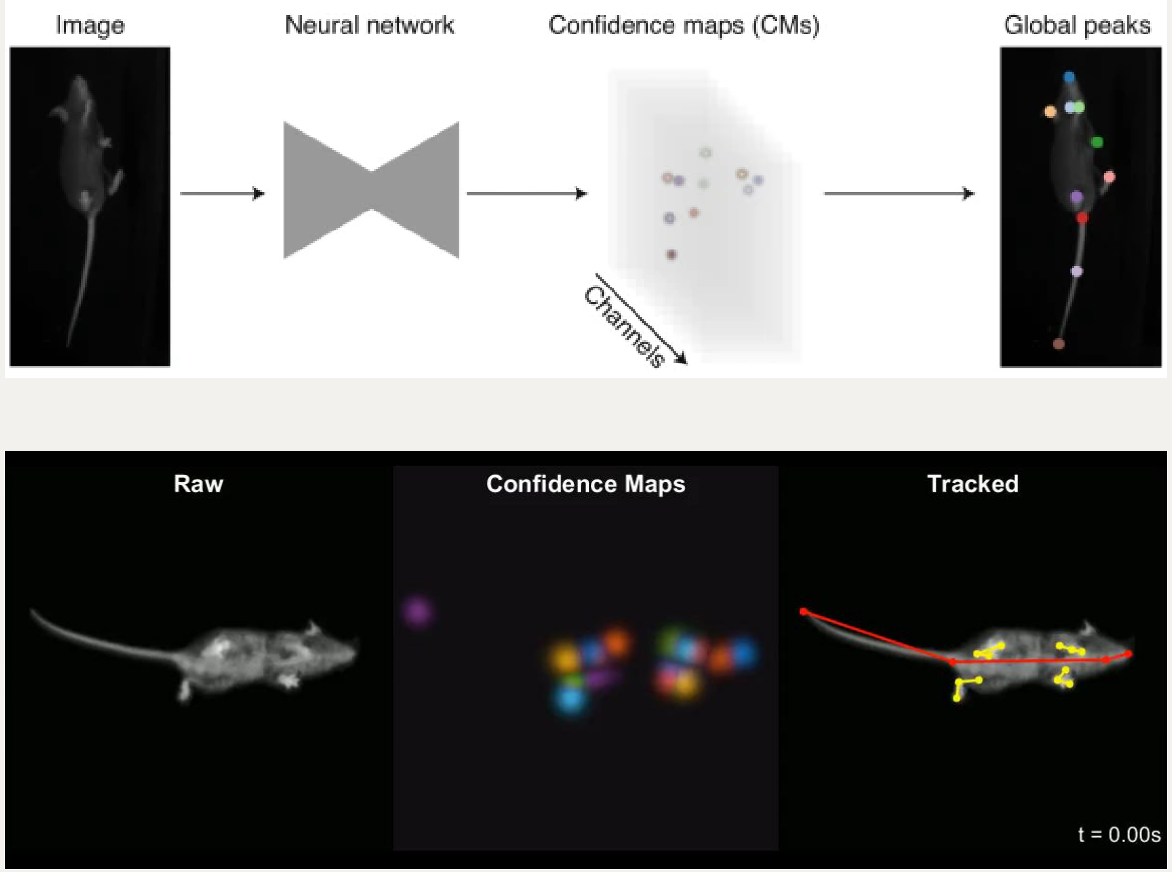
(Mathis et al., 2018)

SLEAP

Pereira et al., 2019

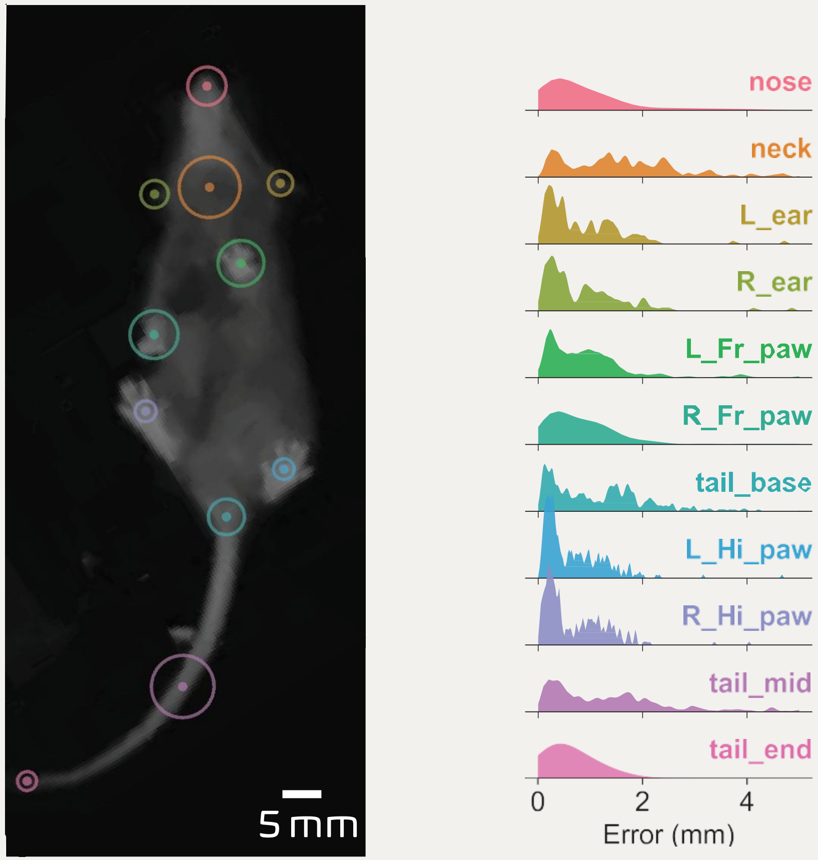
DeepPoseKit (Graving et al., 2019) ; OptiFlex (Liu et al., 2021) ; SemiMultiPose (Blau et al., 2022); Anipose (Karashchuk et al., 2021); CAPTURE (Marshall et al., 2020); YOLO family methods and other

Anatomy of pose estimation systems

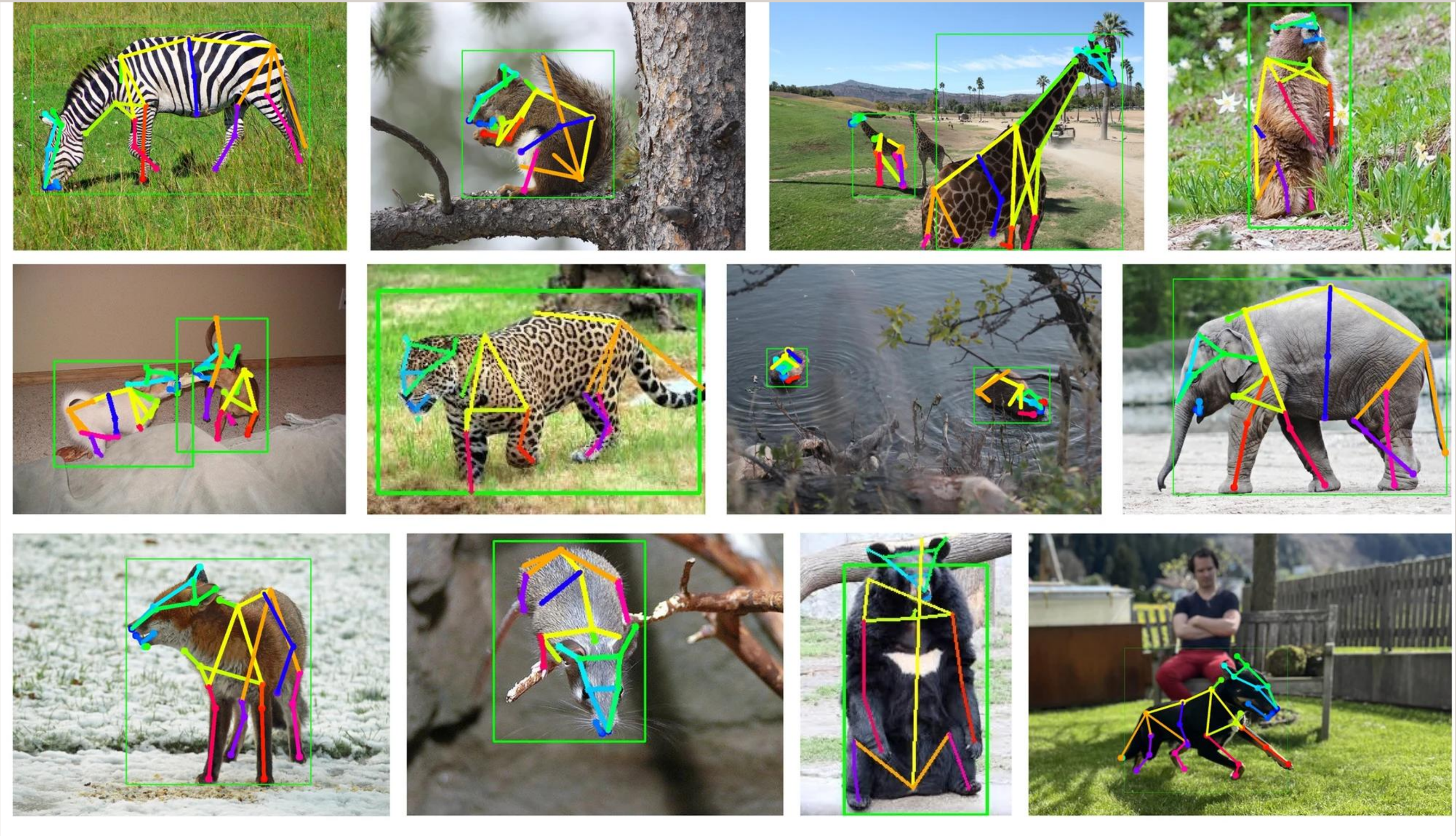


LEAP and SLEAP
Pereira et al., Nat Methods 2019
Pereira, Shaevitz & Murthy. Nat Neurosci 2020
Pereira et al., Nat Methods 2022

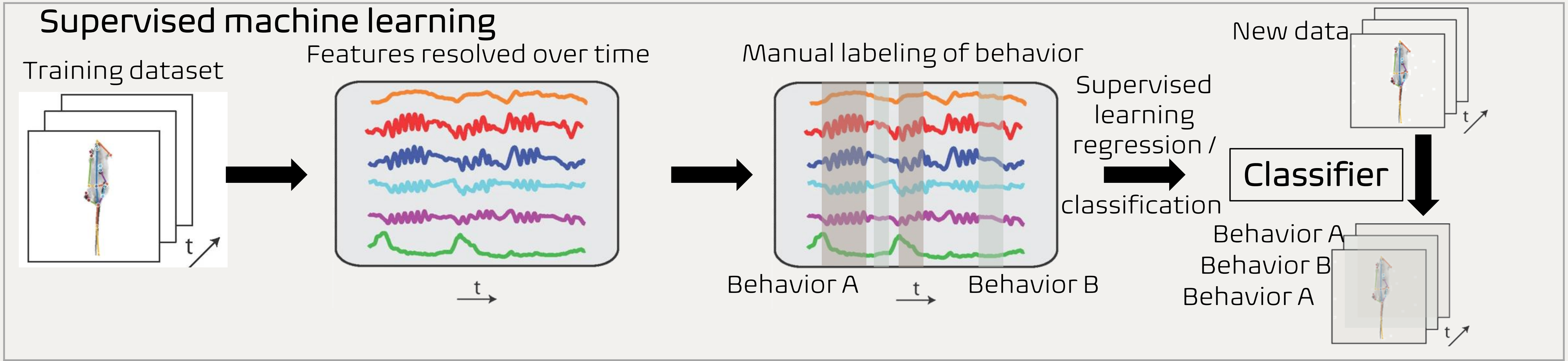
Accurate body landmark localization

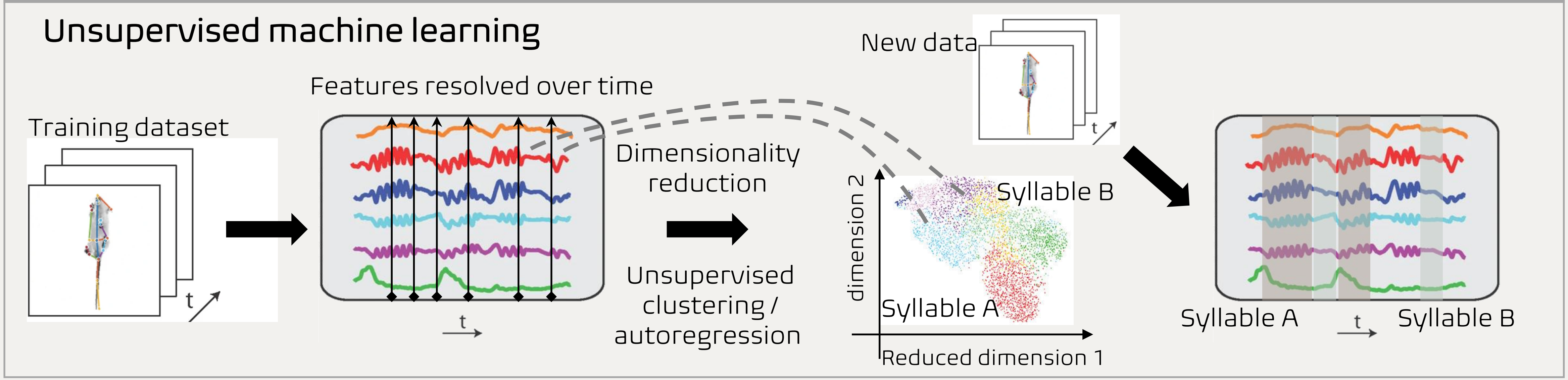


03 Making sense of posture dynamics



Supervised and unsupervised machine learning for behavior classification





Supervised machine learning approach

Popular approaches to classify behavior based on human definitions:

- JAABA (Kabra et al., 2013)

  Support Vector Machine based
- SimBA (Nilsson et al., 2020 and Goodwin et al., 2024)

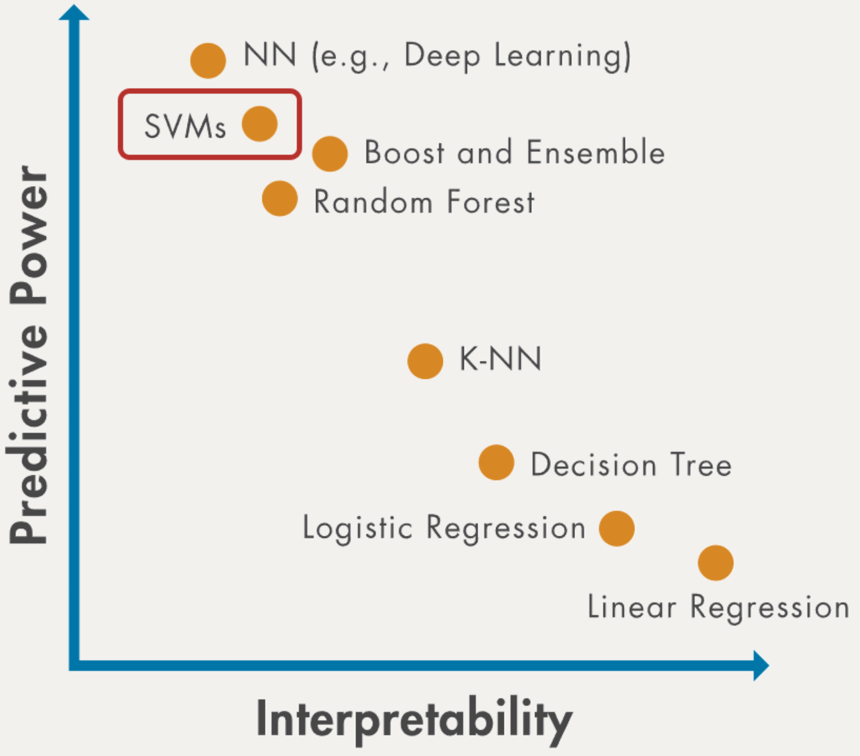
  Random forest, Gradient boost classifier(GBC)

  or eXtreme Gradient boost (Xgboost)
- MARS (Segalin et al., 2021)

  set of 270 spatiotemporal features and Xgboost
- DeepEthogram (Bohnslav et al., 2021)

  deep convolutional neural networks
- BehaviorDEPOT (Gabriel et al., 2022)

  heuristics (thresholding pose-based metrics)
- A-SOiD (Tillmann et al., 2024) - Random Forest Classifier



Unsupervised machine learning approach

Popular approaches to classify behavior without human definitions:

- MoSeq (Wiltschko et al., 2015) and Keypoint-MoSeq (Weinreb et al., 2024)

  Auto-regressive hidden Markov model (AR-HMM)

- MotionMapper (Berman et al., 2014)

  Model behavior in frequency space

- B-SOiD (Hsu and Yttri, 2021)

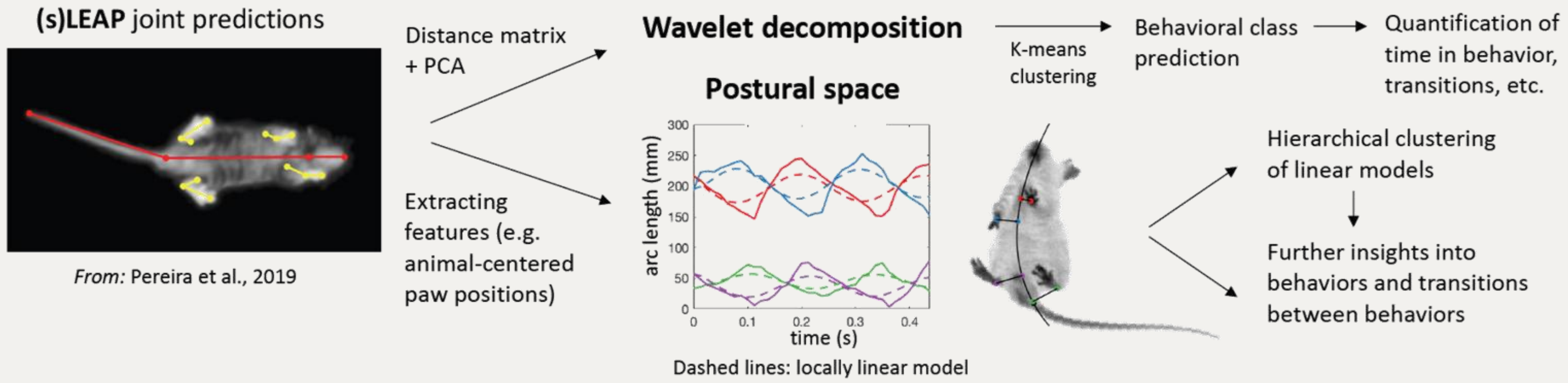
  Reduce dimensions of spatiotemporal pose with UMAP

- VAME (Luxem, K. et al. 2022)

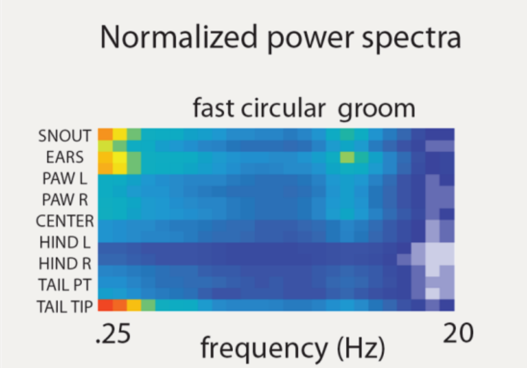
  deep variational embeddings of animal motion

Unsupervised behavioral classification for a non-goal oriented task

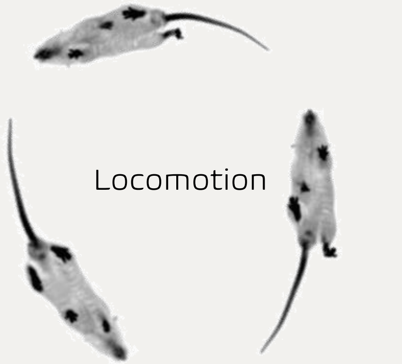
Modeling mouse behavior as a clusters of body postures in frequency space

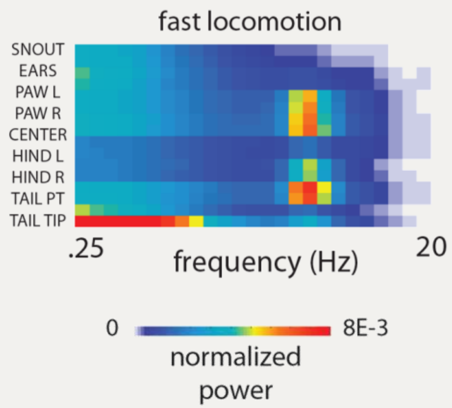


Circular grooming



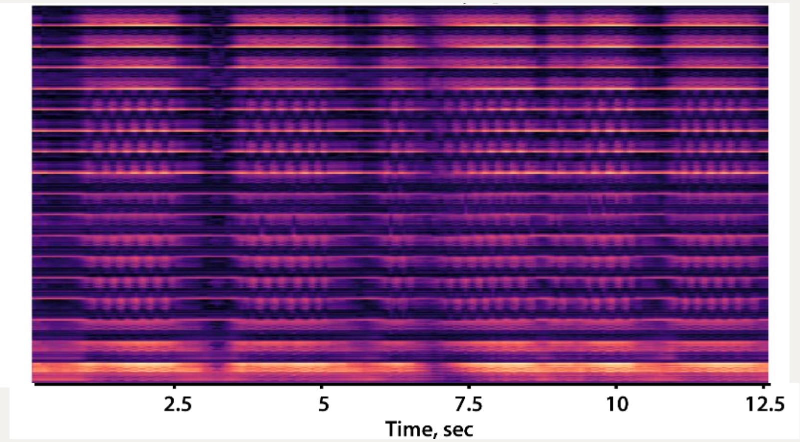
Locomotion



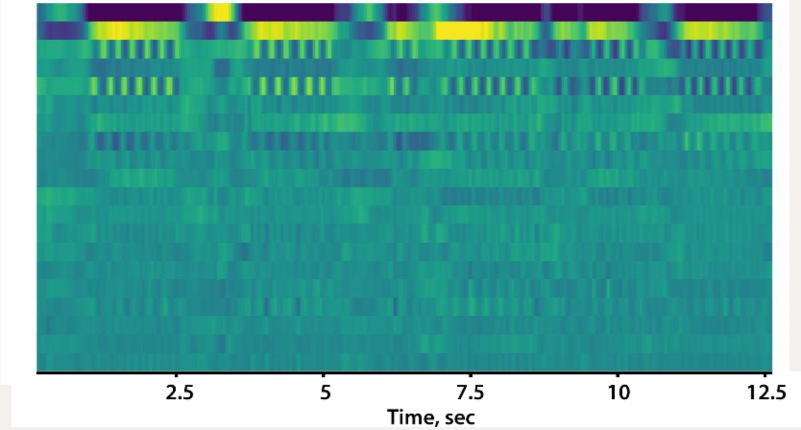


Modeling mouse behavior as a clusters of body postures in frequency space

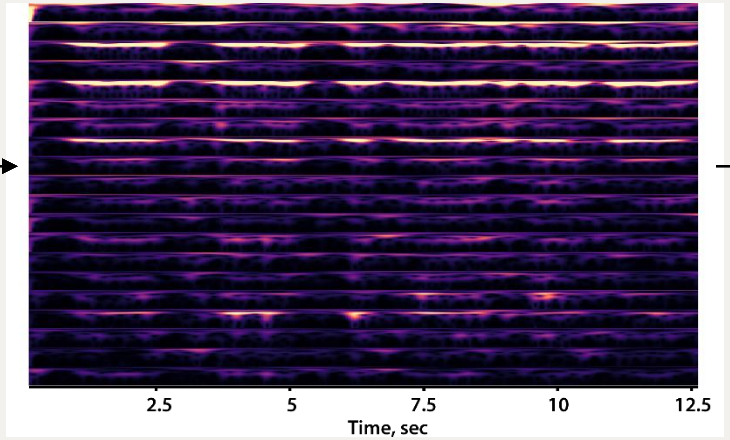
Distance between all body part coordinates



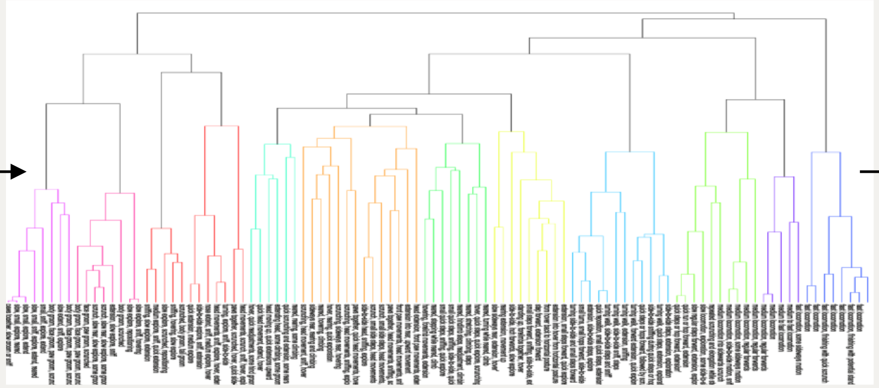
PCA projections



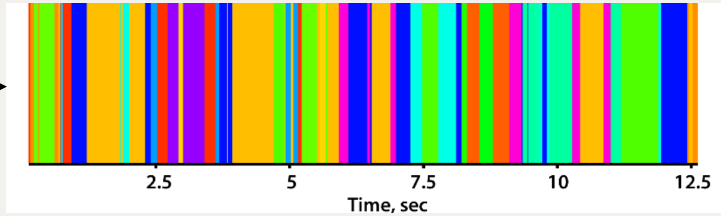
Power spectral densities



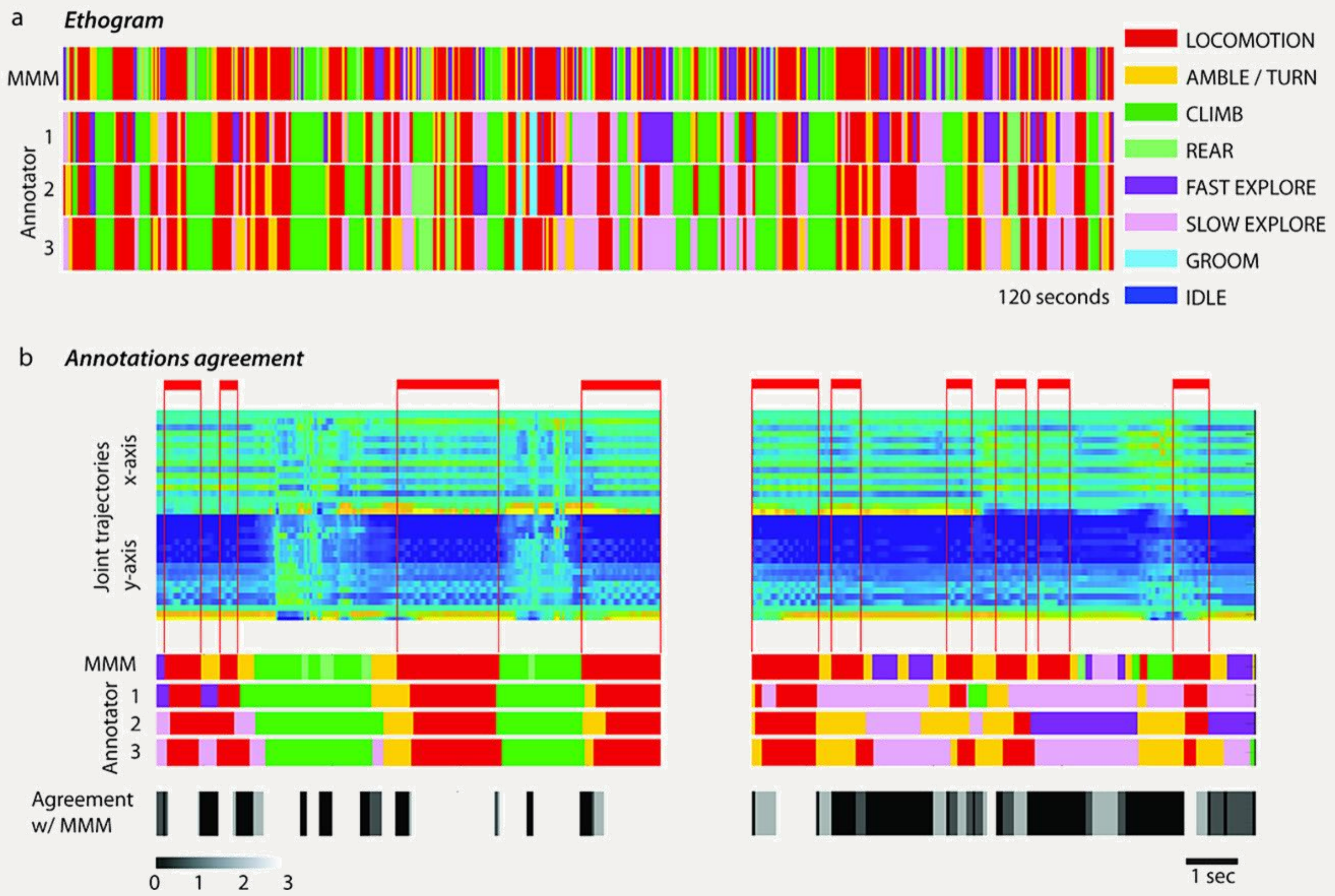
Clustering in high-dimensional wavelet space

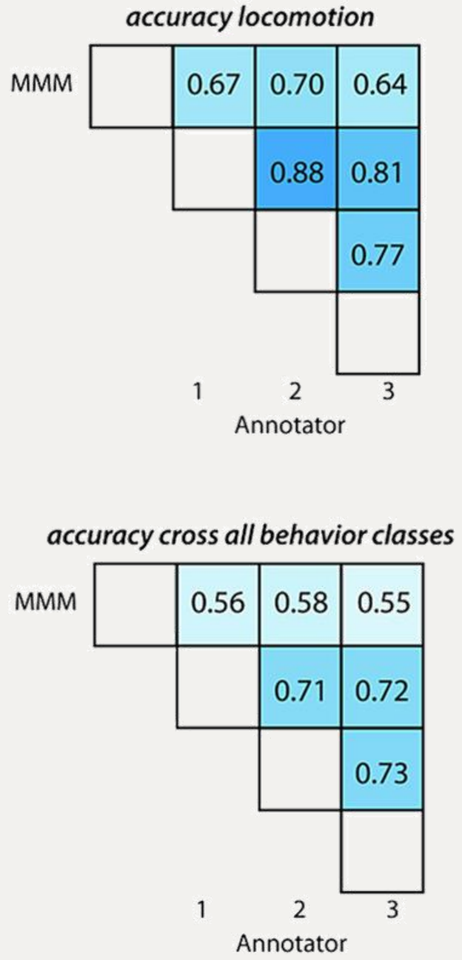


Ethogram of clusters



Agreements and discrepancies between *MMM* and human annotators





Inter-annotator style differences

Time to practice
Open the Google Colaboratory (Colab)