DeepLabCut AI Residency

Day 1 Session 1:
Introduction to Machine Learning and DeepLabCut

July 30 & August 1, 2025

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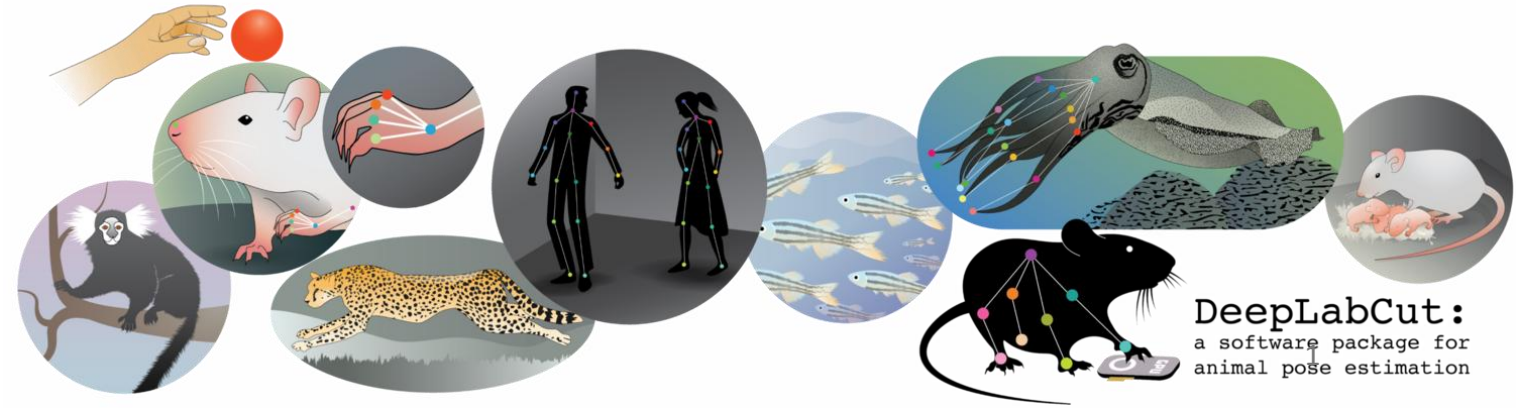


What is Machine Learning?

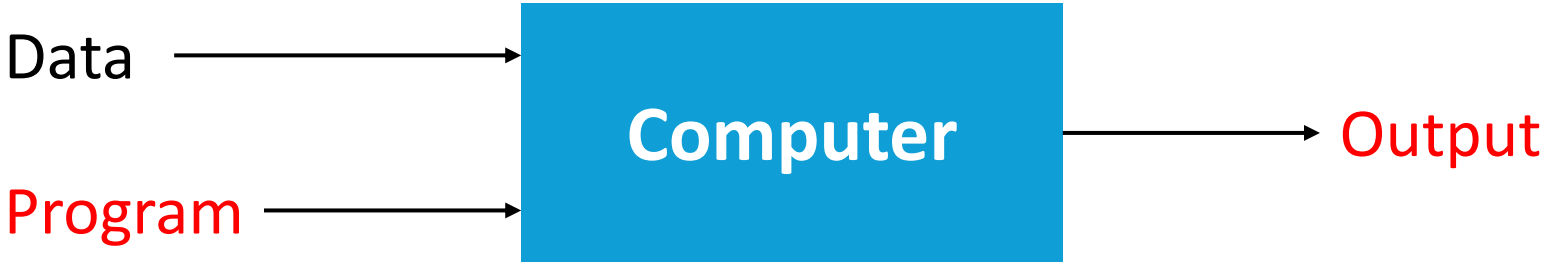
“Learning is any process by which a system improve performance from experience.”

- Herbert Simon

Definition by Tom M. Mitchell:

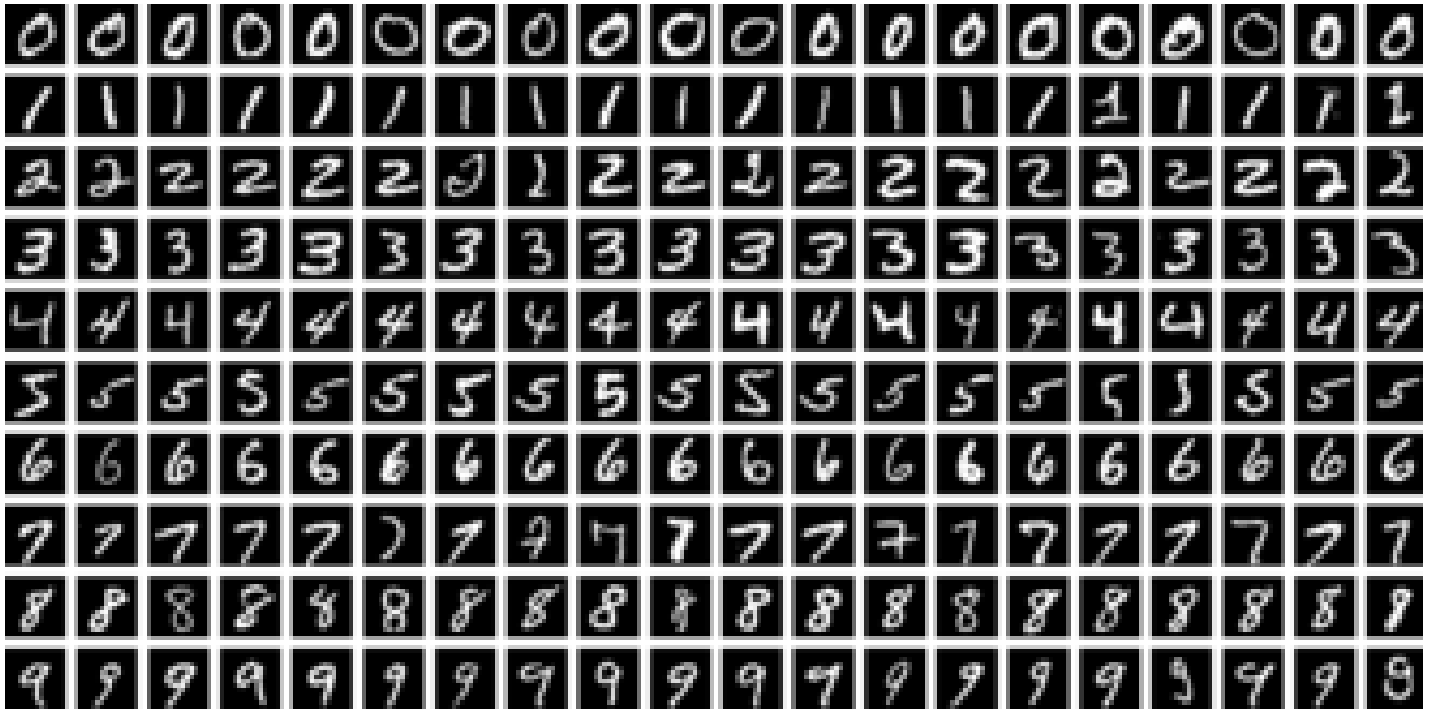
Machine learning program gets better at a **specific task (T)** as it gains **more experience (E)**, and this improvement is measured by a defined **performance (P)** metric.

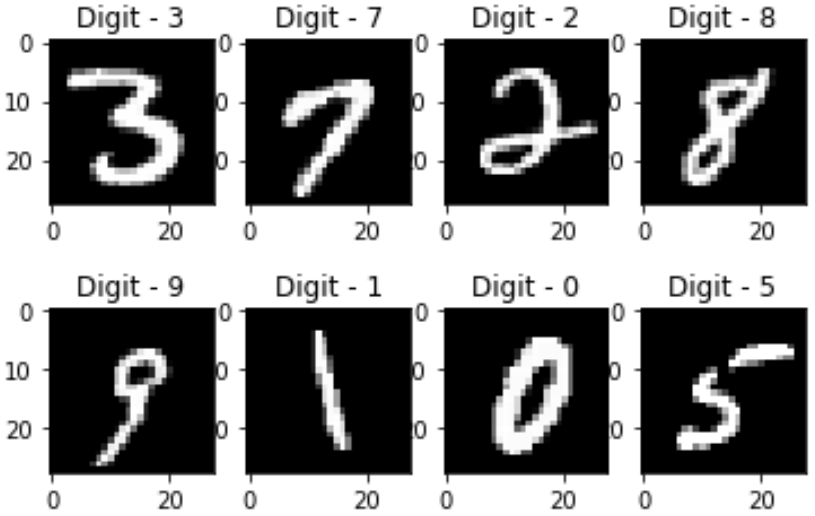
Typical coding program



Machine learning

An example task that uses machine learning:
- Digit recognition (MNIST dataset)



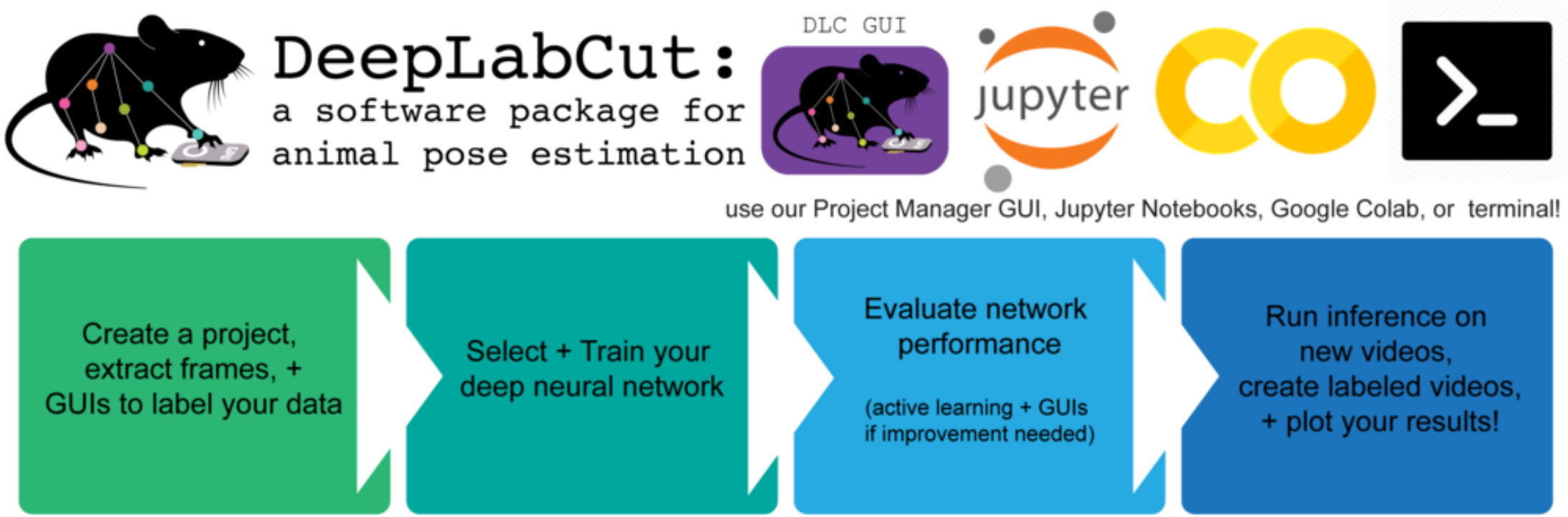


L. Deng, "The MNIST Database of Handwritten Digit Images for Machine Learning Research“ (2012)

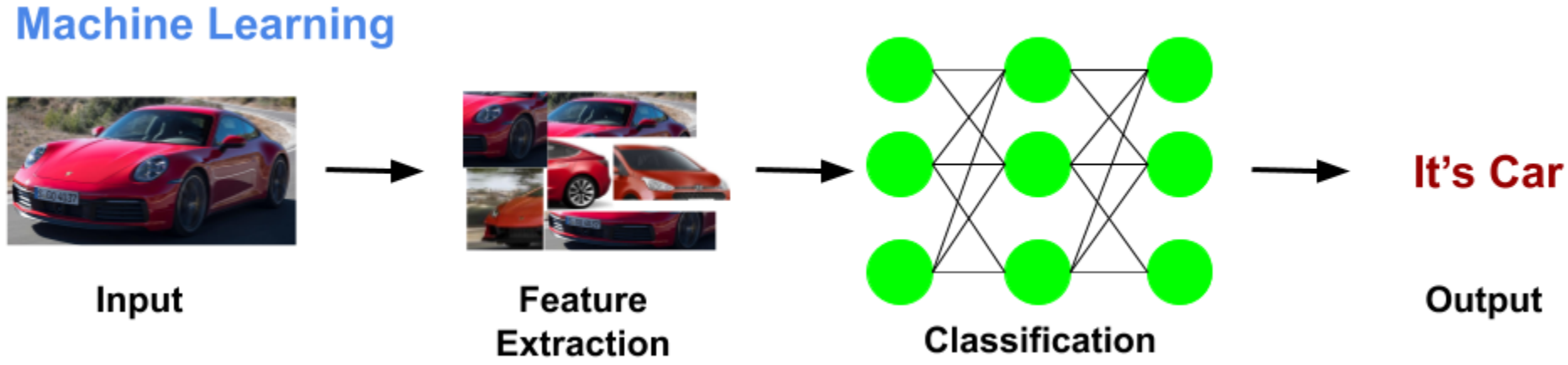
Some example tasks solved by machine learning algorithms:

- Prediction
  - Identify fraudulent transactions in finance
  - Forecast house price by locations and sizes
- Patterns generation
  - Generate images
- Recognition
  - Face identities and expression recognition
  - Images recognition (hand-writing, medical images, etc.)
  - Pose estimation (**e.g. DeepLabCut**)

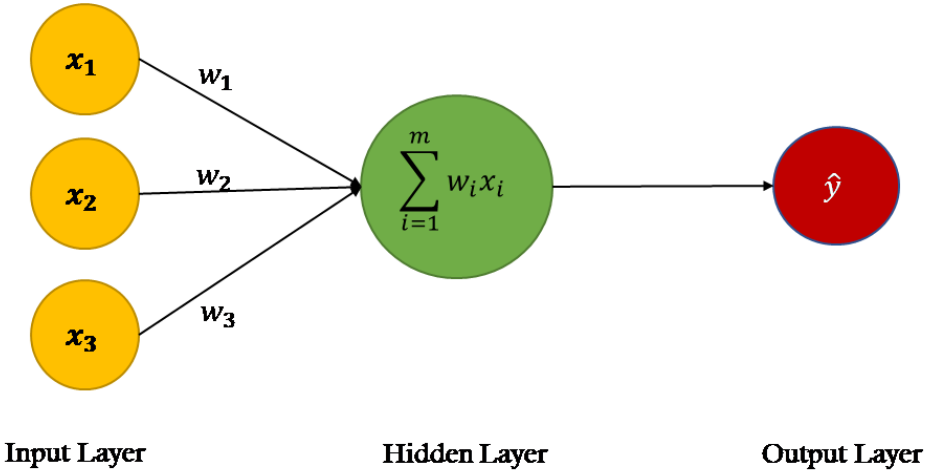
DeepLabCut: markerless pose estimation with deep learning



Machine learning vs. Deep learning



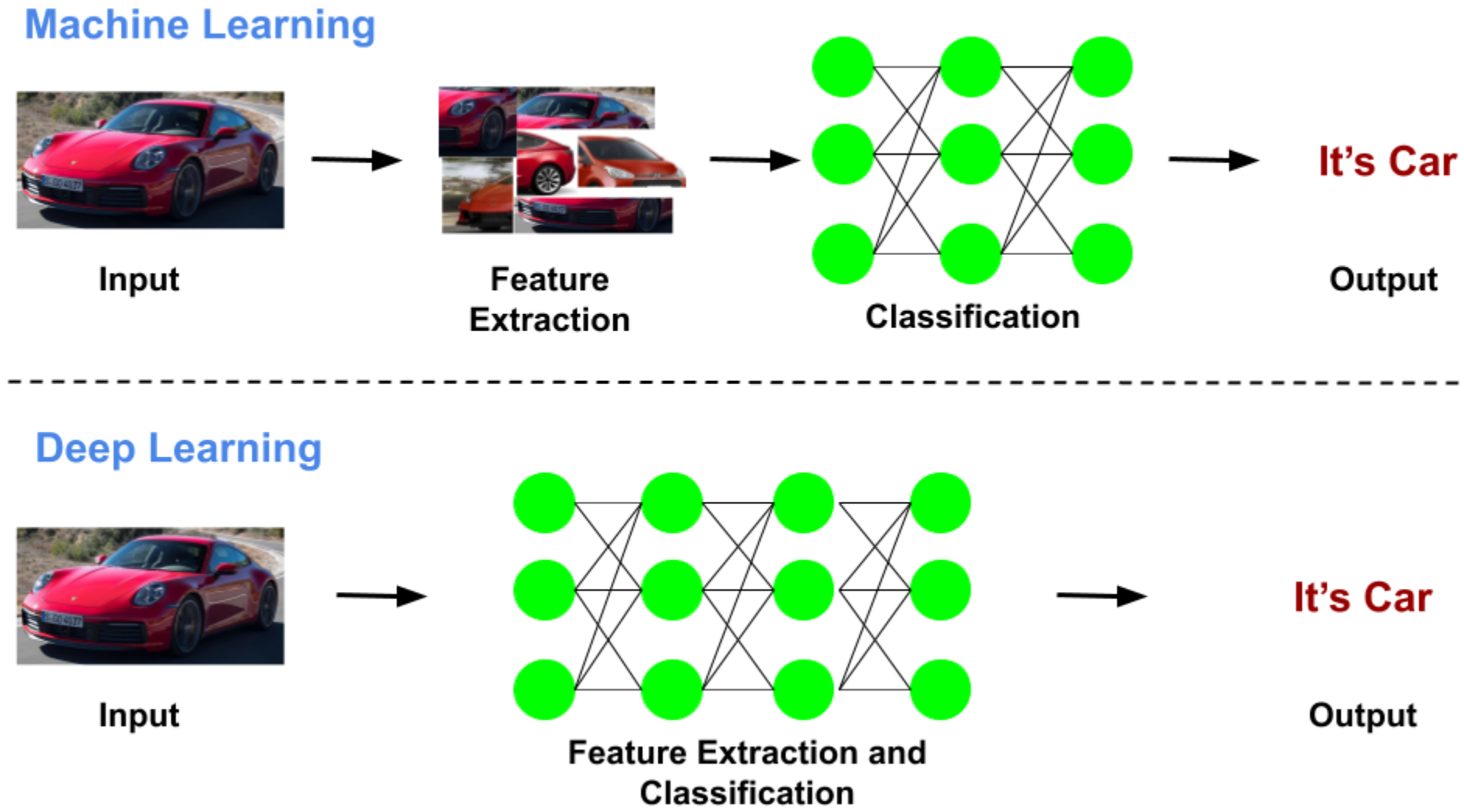
A "**network**" of linear model:



Limit of linear model":

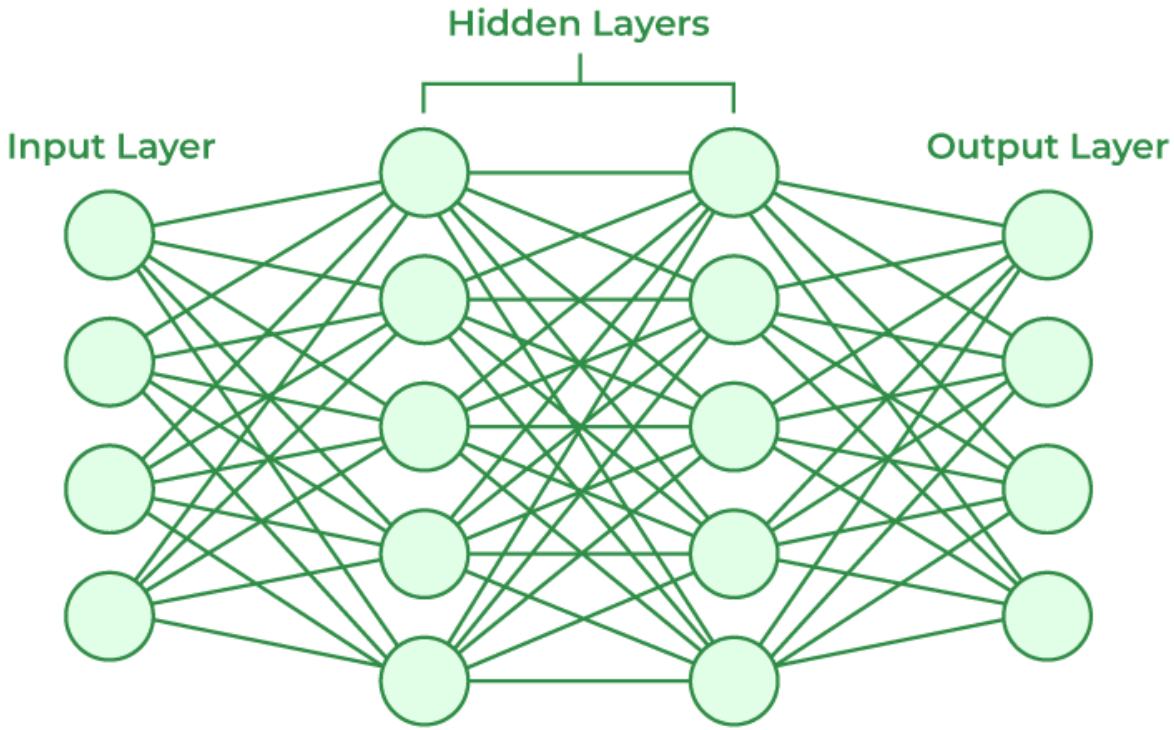
- Cannot model non-linear
- Underfitting
- Sensitive to outliers
- Cannot capture feature interactions
- Etc.

Machine learning vs. Deep learning



Deep learning

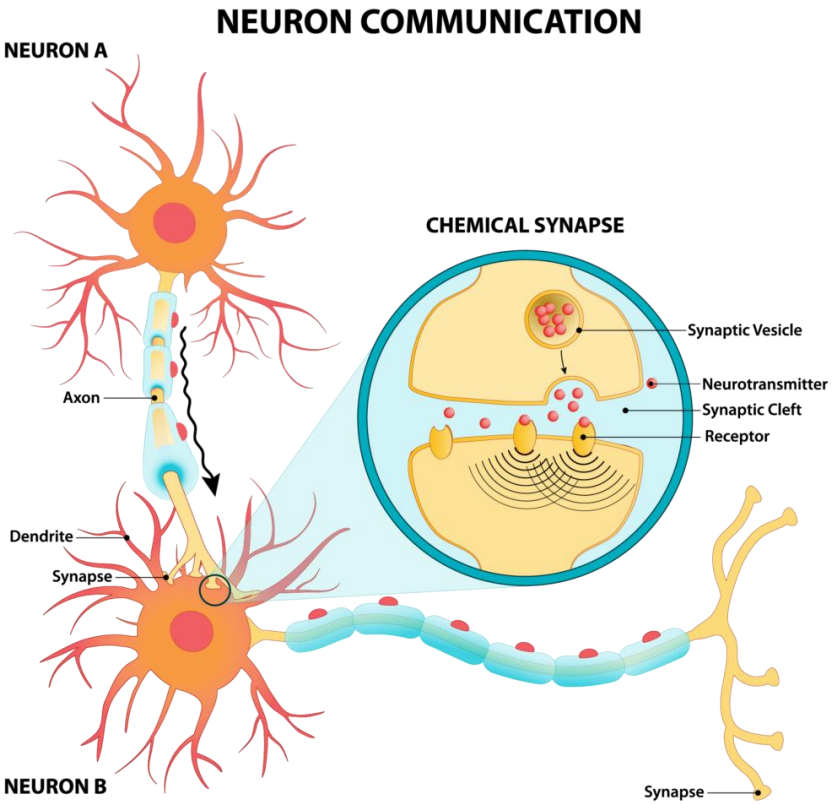
- A subset of machine learning algorithms that allow software to train themselves to perform tasks, using **multi-layered neural network**.



More (hidden) layers
= deep learning

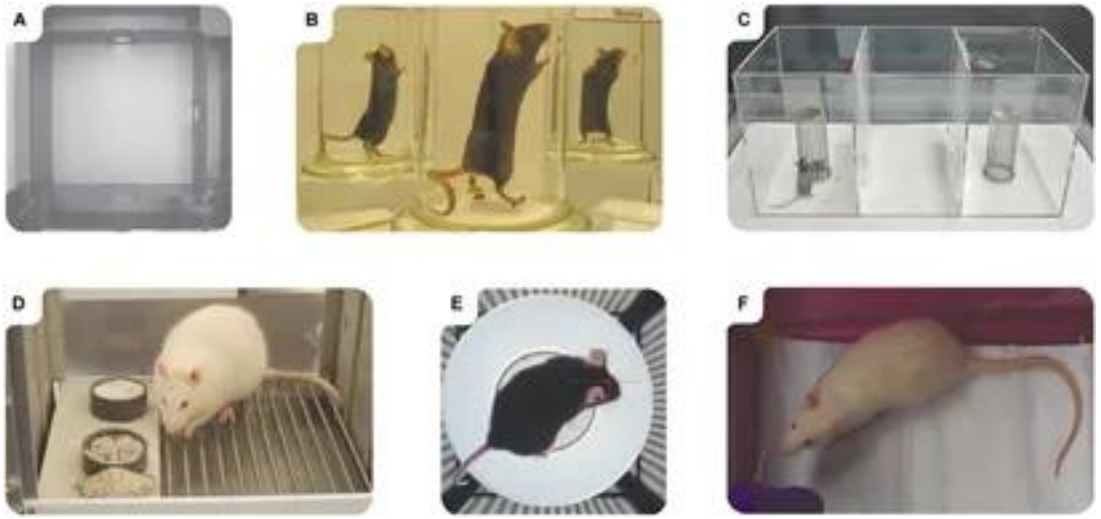
The use of more layers (i.e. depth)?

- Each layer = 1 processing step
- Multiple layers (i.e. processing steps) allow complex function to be interpreted
- Neural network
  - A sequence of layers
- Similarity to human neurons and connections
  - Vastly simplified computation within neuron
  - Discrete timestep
- Example
  - DeepLabCut



Queensland Brain Institute. Action potentials and synapses. (2017)

Traditional behavioral analysis

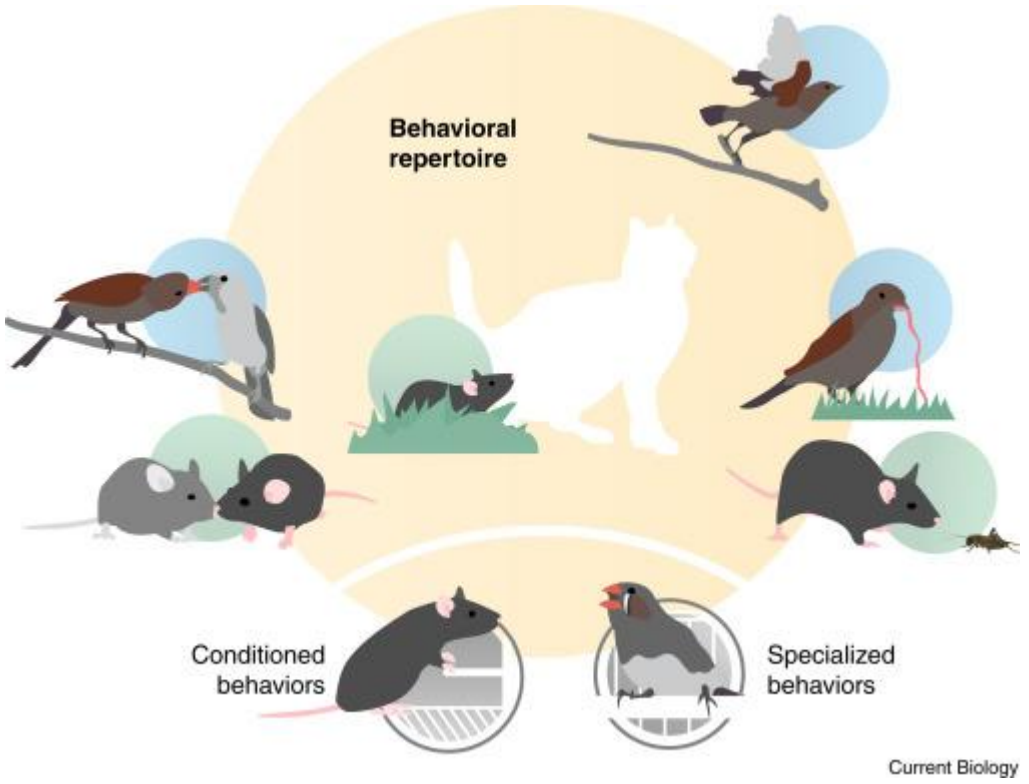


Rodent behavioral tests.

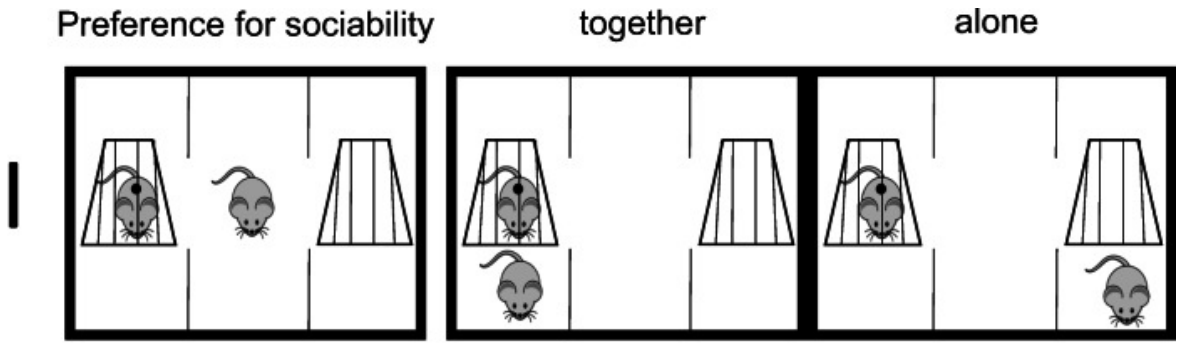
Hånell & Marklund (2014). Front. Behav. Neurosci.

Animal behavioral repertoire.

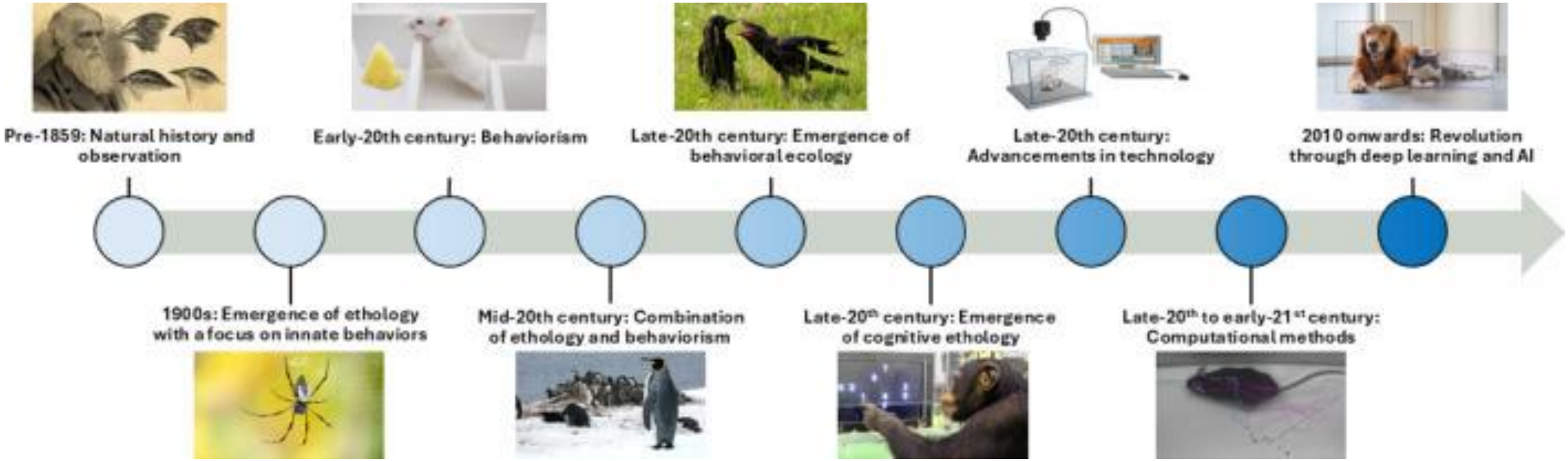
Miller et al. (2022). Current Biology.



Limitations of traditional analysis

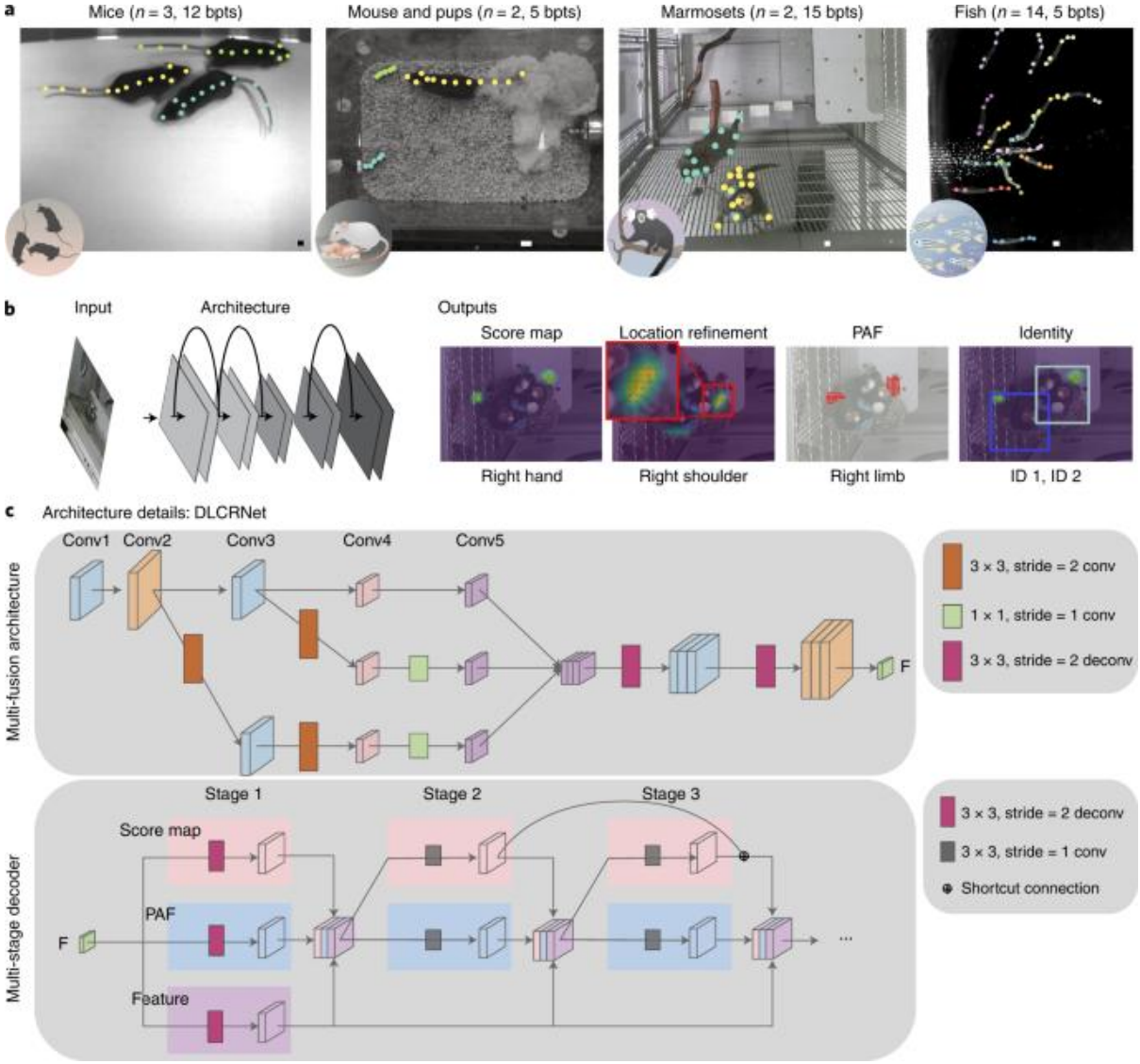


Three-chamber test scheme.
Gasser et al. (2020). Naunyn Schmiedebergs Arch Pharmacol.

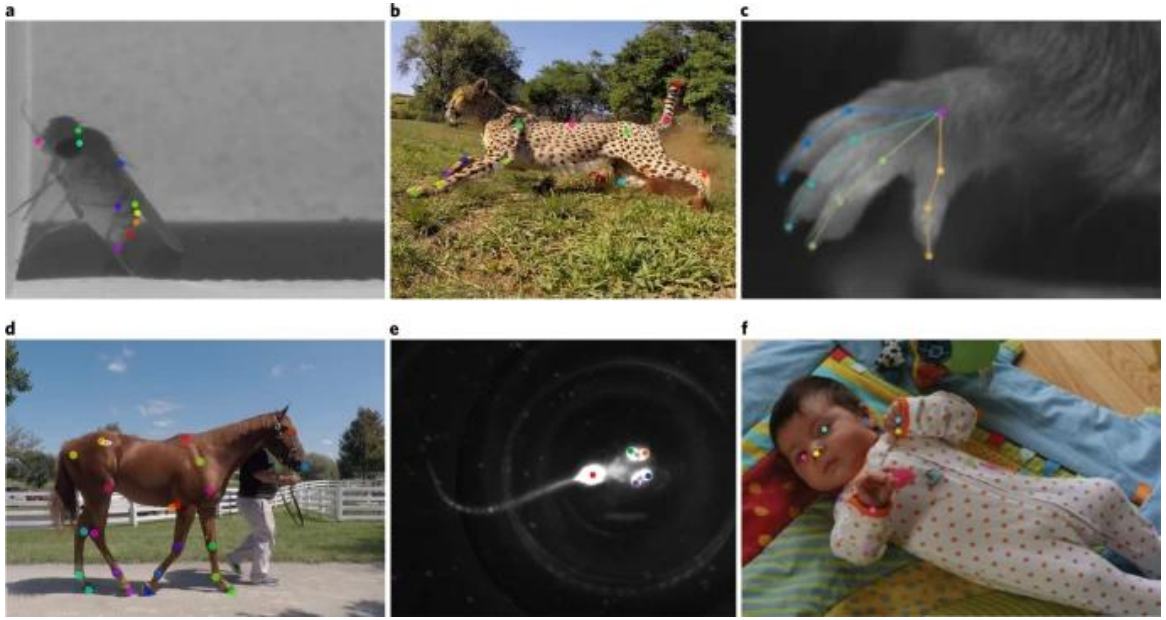


Timeline in animal behavior analysis advancement. Saoud et al. (2024). Ecological Informatics.

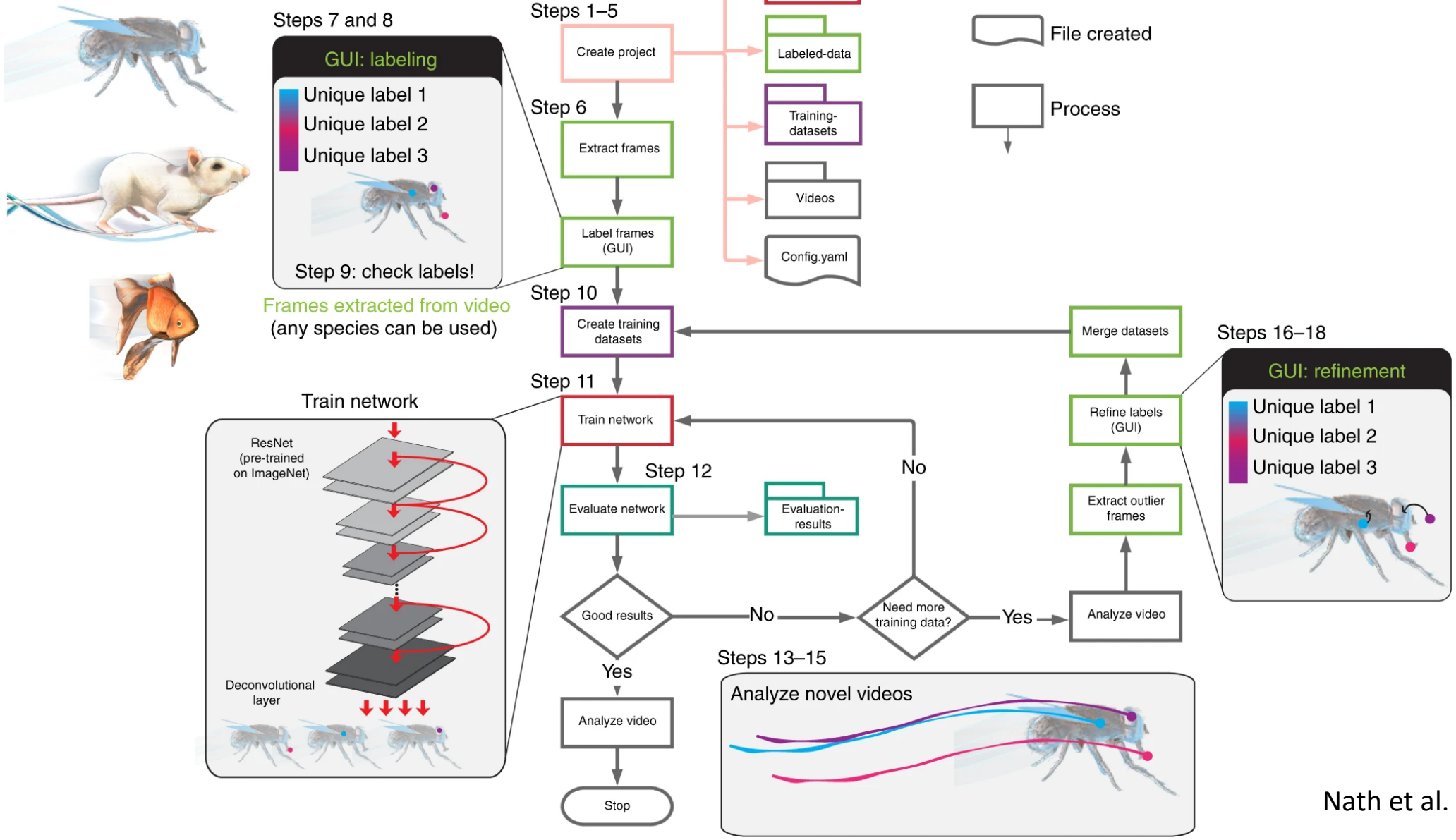
Why DeepLabCut & deep learning?



Lauer et al. (2022). Nature Methods.

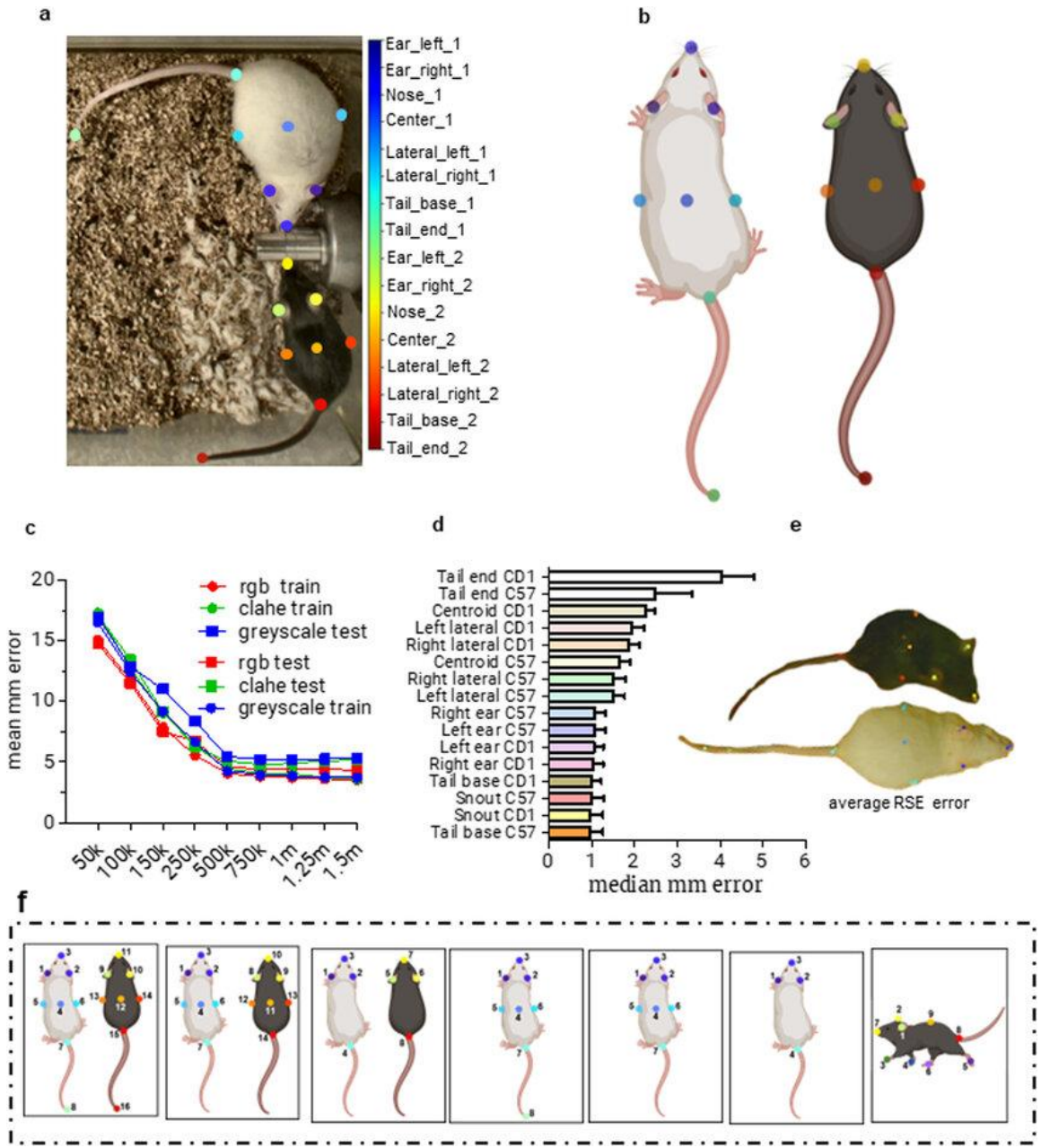


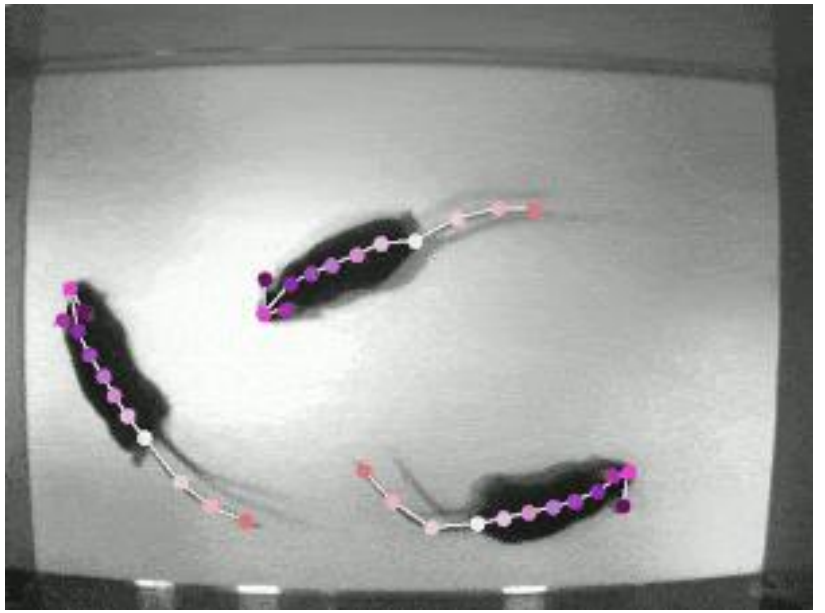
Nath et al. (2019). Nature Protocols.



Nath et al. (2019). Nature Protocols.

Example of pose estimation

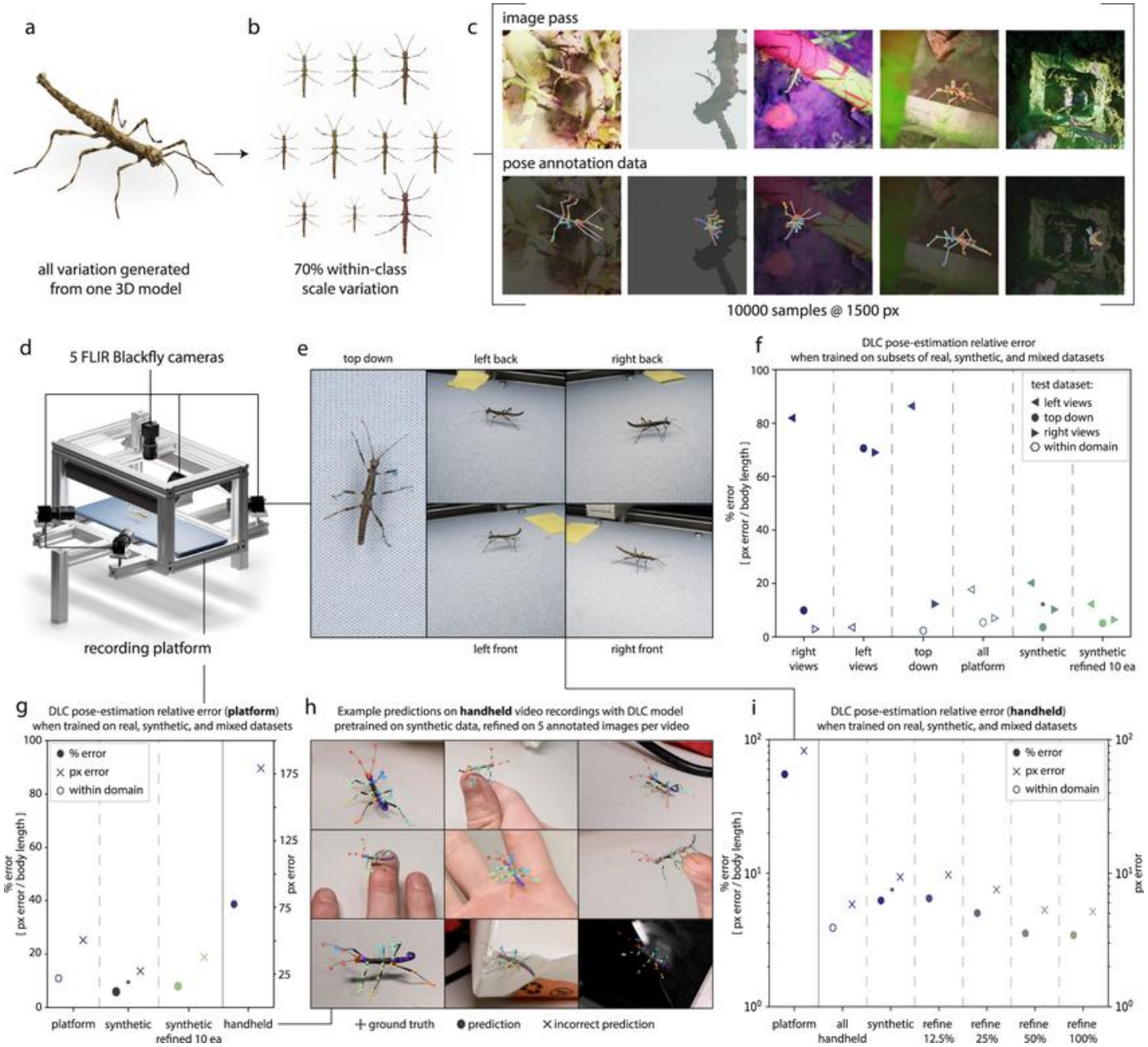




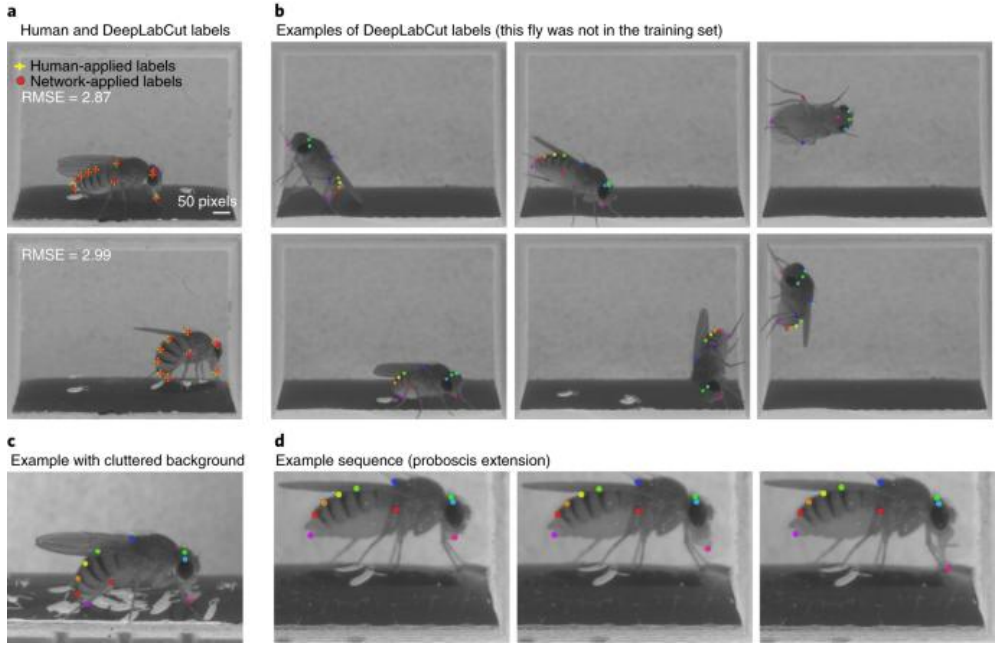
DeepLabCut demo mice

https://www.mackenziemathislab.org/deeplabcut

Goodwin et al. (2024). Nature Neuroscience.

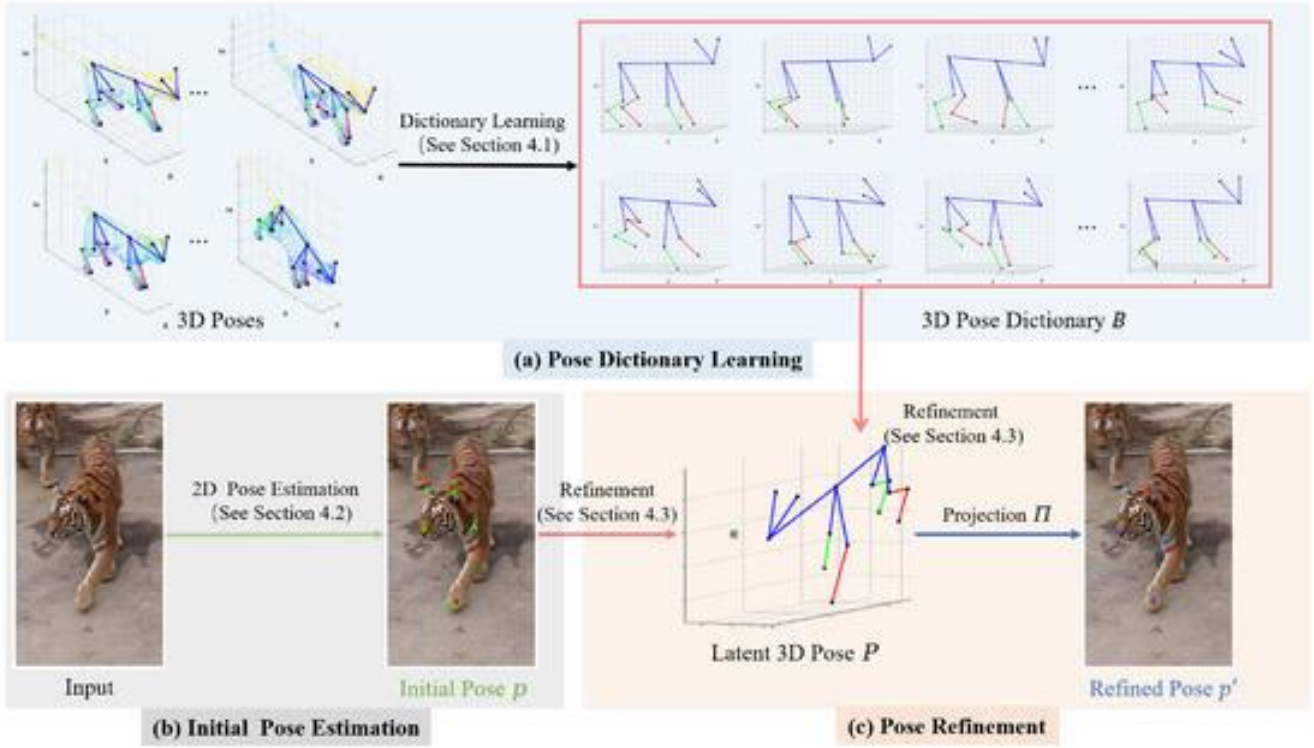


Plum et al. (2023). Nature Communications.

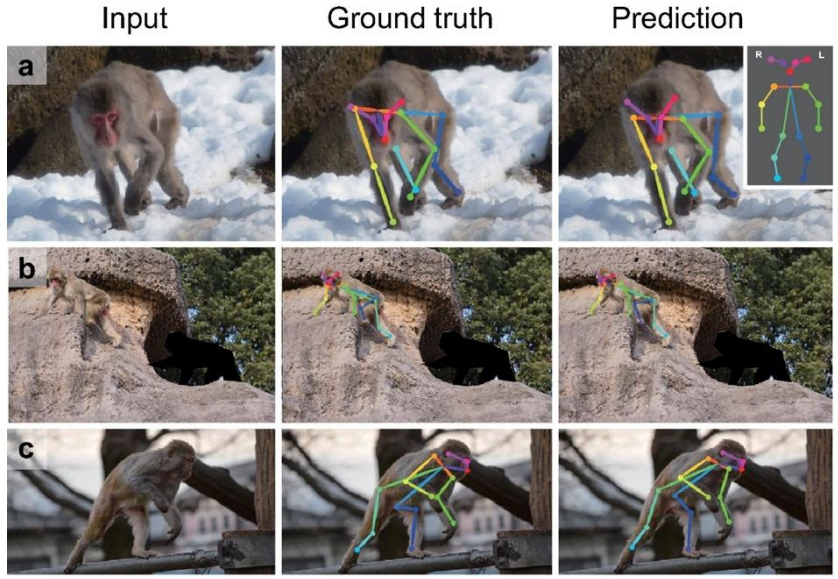


DeepLabCut application (insects)

Mathis et al. (2019). Nature Neuroscience.

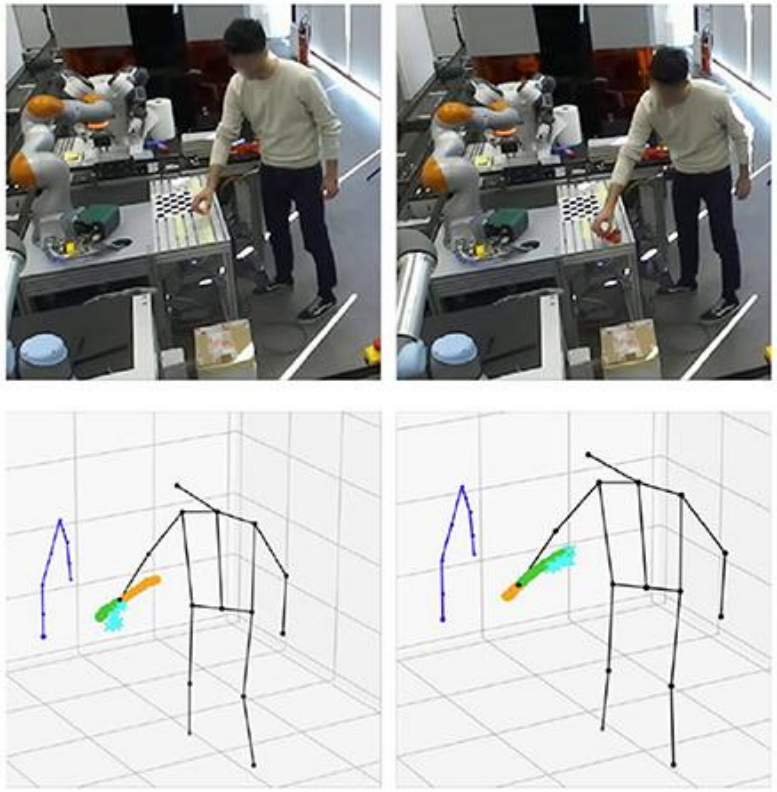


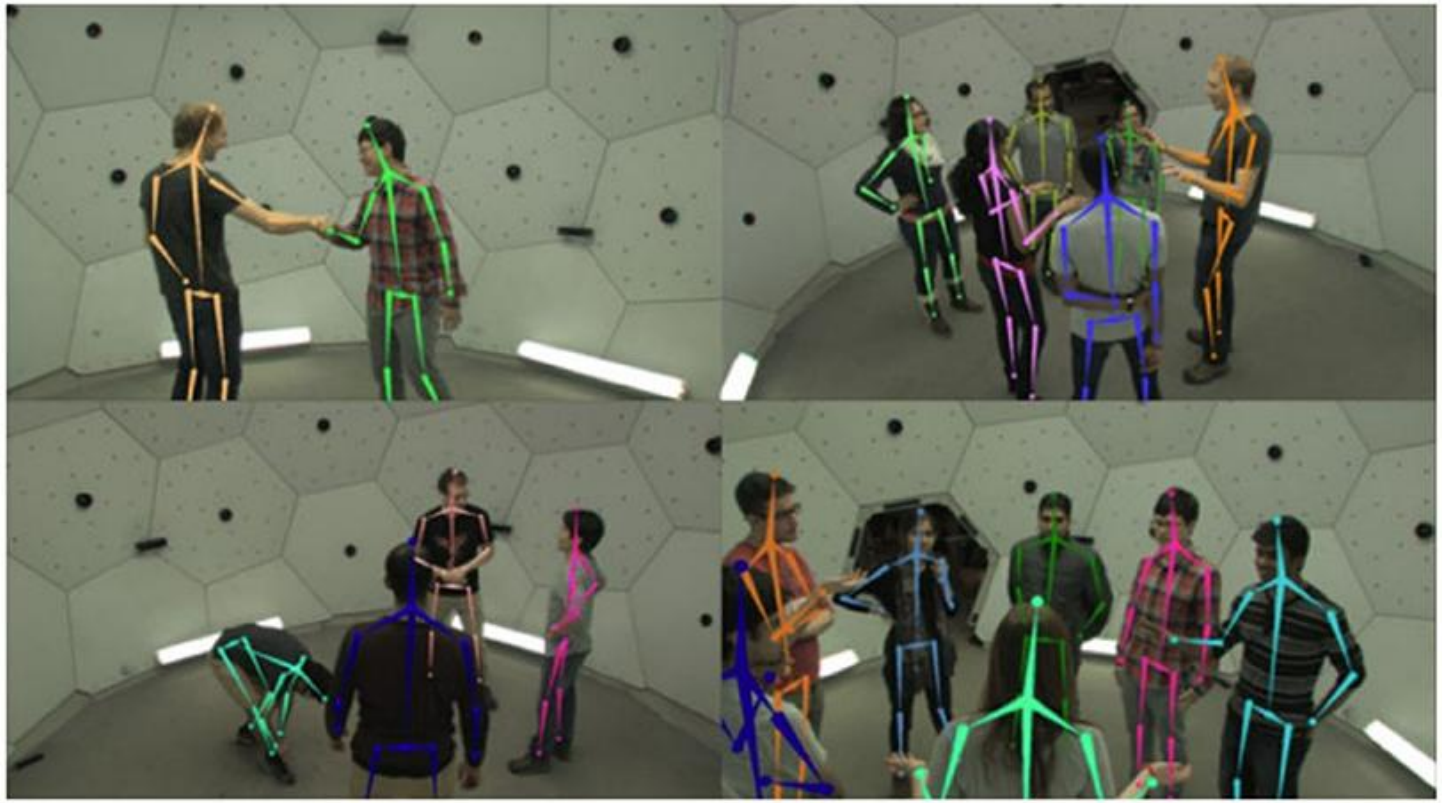
Labuguen et al. (2020). Biorxiv pre-print.

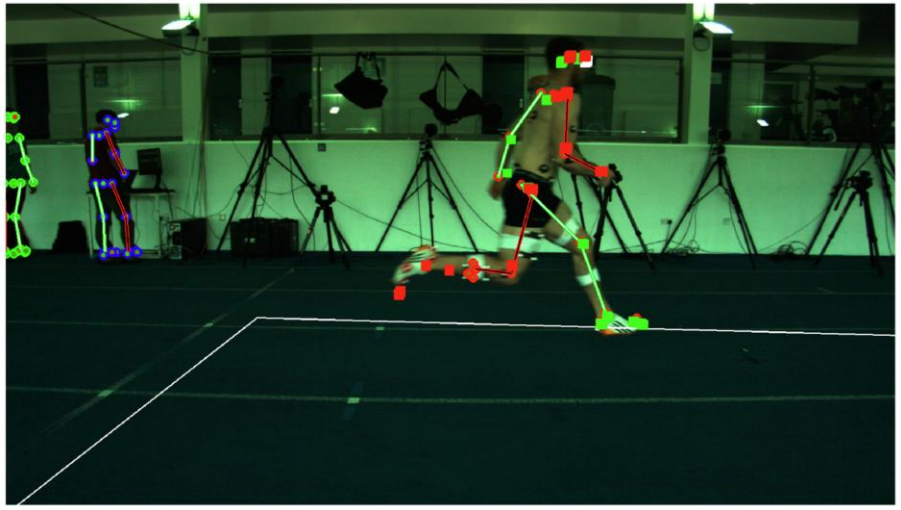


Animal/wildlife pose estimation.

Dai et al. (2023). Applied Sciences.

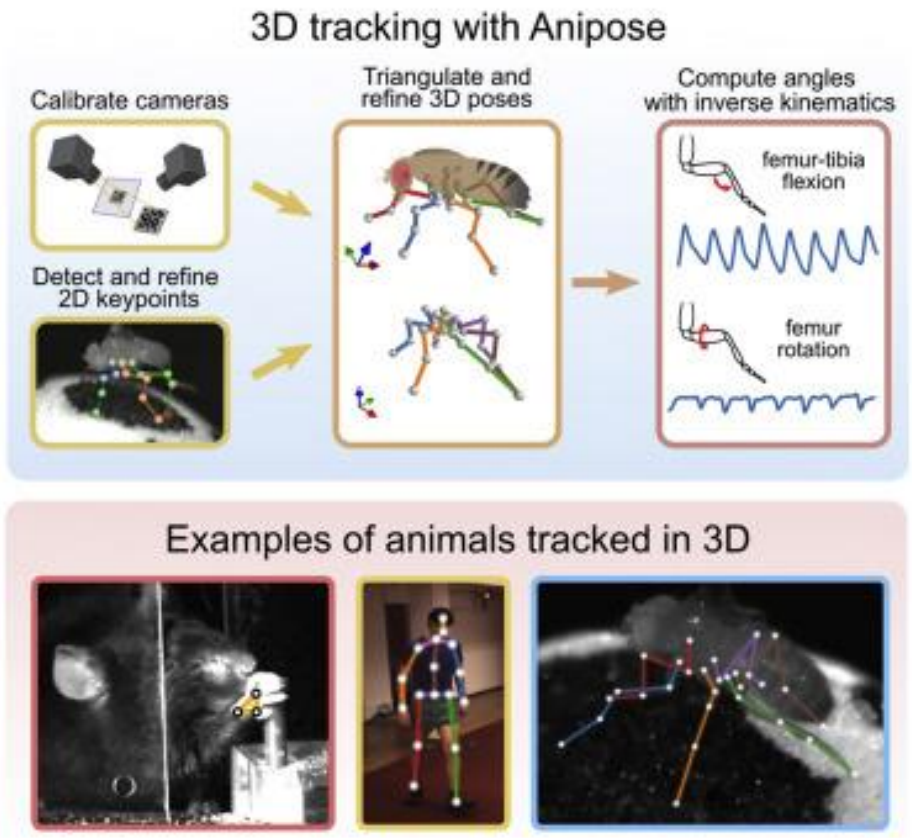


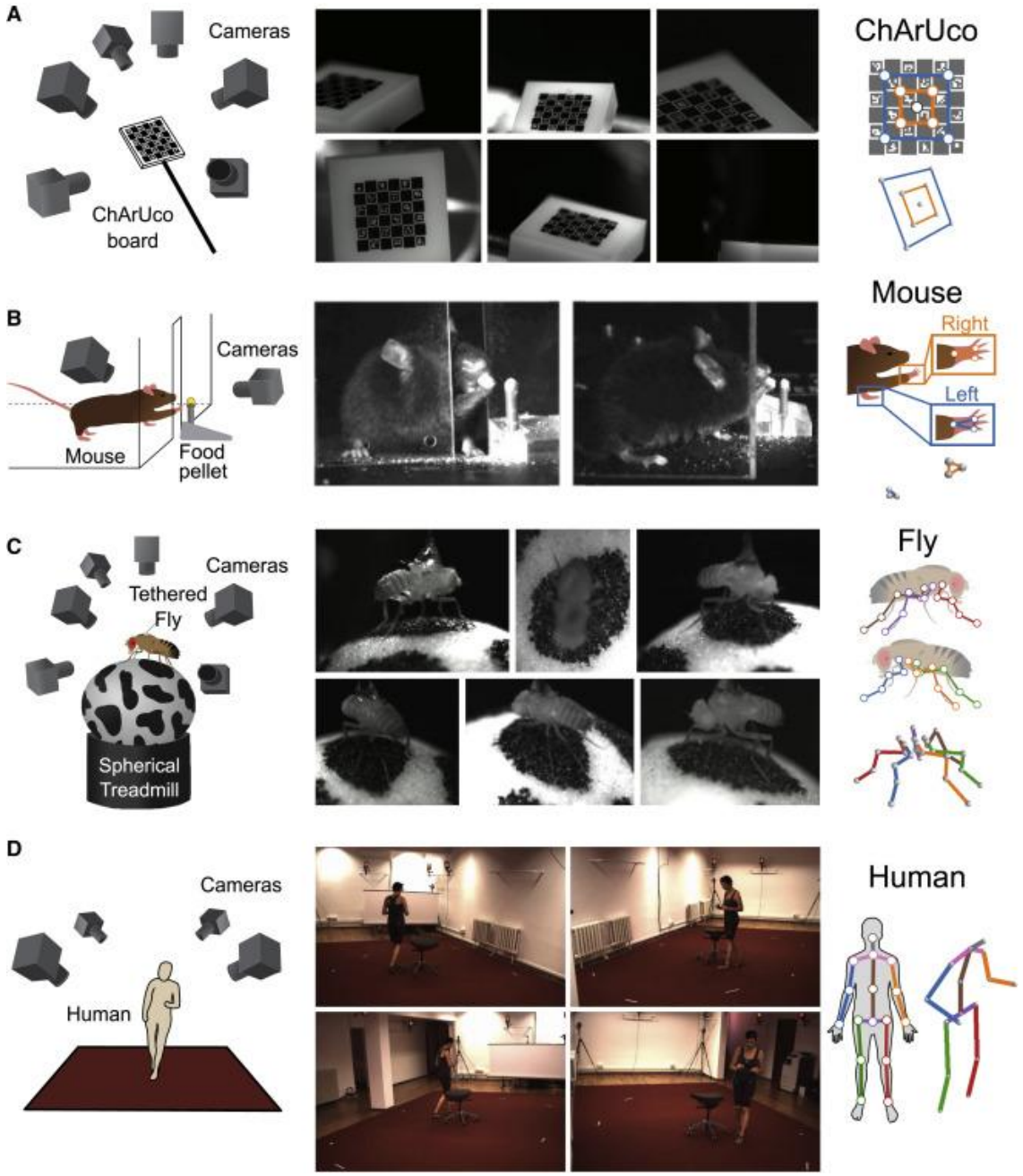




Human pose estimation

Avogaro et al. (2023). Front. Comput. Sci.
Needham et al. (2021). Sensors



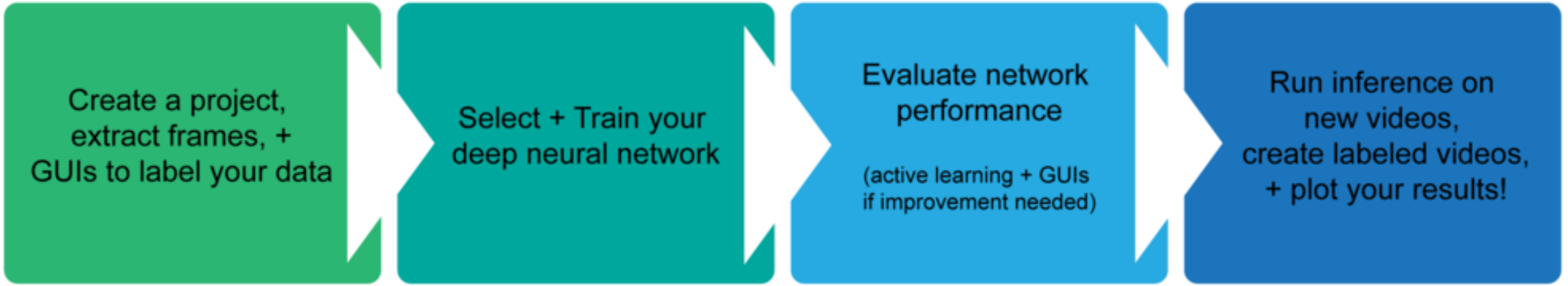


3D pose estimation

Karashchuk et al. (2021). Cell Reports.

DeepLabCut AI Residency

- Decromatize AI-based behavioral analysis
- Empower individuals with diverse community to learn about the open-source community
- **Walk through the steps from project creation to video analysis**



Nath et al. (2019). Nature Protocols.