Master Thesis Proposal Nr:

Topic: Automated Tracking and Action Recognition for Mice

In experimental research, scientists often have to identify mouse behaviors manually. However, as noted by Dr. Zimmermann and medical student Nicole Richter, manual labeling is not only time-consuming, but also requires days of training researchers to annotate videos. This highlights the need for more efficient automated labeling methods.

Implementing an algorithm that automatically detects mice behavior can significantly enhance the reproducibility of experiments by ensuring consistent use of the same setup, such as the Cold Plate, alongside the corresponding algorithm. While there are existing setups for observing mouse behavior, they are typically tied to specific configurations, such as those utilizing specialized infrared sensors or depth sensors [2, 6].

The university hospital collaborates with Ugo Basile (Gemonio, Italy) [5], a leading developer of behavioral research equipment. For this research of detecting pain behavior related to the sensitivity to cold, a specialized setup is employed, which features a cold plate that allows for bottom-view visualization of the mice. High-resolution videos (200 fps, RGB color) are recorded over 5 minutes. Pain-related behaviors are identified through the following actions: 1. Lifting, 2. Shaking, wagging, flinching, 3. Biting, licking of the affected paw, and 4. Toe spreading.
Developing a custom algorithm for this setup, or adapting state-of-the-art algorithms originally designed for slightly different scenarios, is valuable because it enables precise and consistent analysis of mice behavior in response to cold sensitivity for our specific use case. Automating the detection and analysis of pain-related behaviors not only minimizes human error but also enhances the reproducibility of results and makes large-scale studies more feasible by reducing the time and labor required.

Goals:

- (Work Package 1) Research the latest state-of-the-art methods, such as DeepLabCut [1] and SLEAP [7], for limb tracking and action recognition in clinical animal videos, with a focus on mice.
- (Work Packages 2-4) Implement and evaluate state-of-the art methods would work for our application of automatically detection pain behavior in mice.
- (Work Package 3) Research which preprocessing methods we would have to implement for our type of mice videos.
- (Work Package 5) Depending on how successful the limb tracking is on our mice videos, the student, if time allows will try out action recognition techniques on our mice videos.
- Following the completion of the master's thesis and depending on the results and progress, an evaluation will determine whether further improvements to the current state-of-the-art methods are necessary.

The proposed work consists of the following parts:

- **Work Package 0 – Getting Started:**
  - Download Zotero (tool for literature research)
  - Understand the Prisma Method (used for literature research)
  - Get familiar with our dataset (how many videos, how do the videos look like, types of annotation).

- **Work Package 1 – Literature Research:**
  - Bibliography on Limb tracking methods from 2015 – 2024 (e.g. DeepLabcut [1], SLEAP [7]) using Prisma method
  - Select 3 open-source Datasets for Limb Tracking that are similar to ours (single animal lab videos)
  - Bibliography on action recognition methods from 2015 – 2024 (e.g. X3D [4], Deep Ethogram [3], ...) using Prisma method
- **Work Package 2 – Limb Tracking:**
  - Comparing at least two state of the art limb tracking methods on the chosen datasets
- **Work Package 3 – Limb Tracking on our dataset:**
  - Test preprocessing methods if needed
  - Study potential dataset bias (e.g. mouse color)
  - Adapt the best limb tracking method(s) on our dataset
- **Work Package 4 – Action Recognition:**
  - Compare at least two state-of-the-art Action Recognition methods on the publicly available datasets
- **Work Package 5 (optional, if time allows) – Action Recognition on our dataset:**
  - Implement and test the best action recognition method(s) on our dataset (test on whole videos and the cropped videos of the paw)

The thesis must contain a detailed description of all developed and used algorithms as well as a profound result evaluation and discussion. The implemented code has to be documented and provided. An extended research on literature, existing patents and related work in the corresponding areas has to be performed.

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Start—End: 01.11.2024—01.05.2025

References

[1] https://www.mackenziemathislab.org/deeplabcut
[2] Bains, R.S., Wells, S., Sillito, R.R., Armstrong, J.D., Cater, H.L., Banks, G. and Nolan, P.M., 2018. Assessing mouse behaviour throughout the light/dark cycle using automated in-cage analysis tools. *Journal of neuroscience methods*, *300*, pp.37-47.http://beyondsports.nl/
[3] Bohnslav, J.P., Wimalasena, N.K., Clausing, K.J., Dai, Y.Y., Yarmolinsky, D.A., Cruz, T., Kashlan, A.D., Chiappe, M.E., Orefice, L.L., Woolf, C.J. and Harvey, C.D., 2021. DeepEthogram, a machine learning pipeline for supervised behavior classification from raw pixels. *Elife*, *10*, p.e63377.
[4] Feichtenhofer, C. (2020). X3d: Expanding architectures for efficient video recognition. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition* (pp. 203-213).
[5] https://ugobasile.com/
[6] Lin, S., Gillis, W.F., Weinreb, C., Zeine, A., Jones, S.C., Robinson, E.M., Markowitz, J. and Datta, S.R., 2024. Characterizing the structure of mouse behavior using motion

sequencing. *Nature Protocols*, pp.1-50.

[7] Talmo D Pereira, Nathaniel Tabris, Arie Matsliah, David M Turner, Junyu Li, Shruthi Ravindranath, Eleni S Papadoyannis, Edna Normand, David S Deutsch, Z Yan Wang, et al. Sleap: A deep learning system for multi-animal pose tracking. Nature methods, 19(4):486–495, 2022.