Master Thesis Proposal Nr:

Topic: Automated Pose Estimation of Mice Paws

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 time-consuming and requires days of training researchers to annotate videos [7]. This highlights the need for more efficient automated labeling methods.

The considered internal dataset consists of high-resolution videos (200 fps, RGB color) of mice recorded over 5 minutes. The mice are filmed from the bottom while on a cold plate [3]. Each mouse has one paw which is sensitive to cold temperatures due to an injection in the hind paw. Pain-related behaviors are identified through the following actions: 1. lifting, 2. shaking, wagging, and flinching, 3. biting and licking of the affected paw, and 4. toe spreading.

Annotations for this task consist in count per videos of each behavior. Due to the weak annotations of the dataset, one possible direction of research is detecting the pose of the affected paw in the videos, and investigate whether it can be correlated to the relevant pain-related behaviors.

While existing setups for automatically observing mouse behavior exist, they are typically tied to specific configurations, such as those utilizing specialized infrared sensors or depth sensors [2, 4, 6]. In addition, they have not yet been tested on our precise use case.

This master's thesis aims to bridge this gap by investigating and evaluating various methods for automatic pose estimation from videos, such as DeepLabCut [1], Lightning Pose [5], and LEAP [7]. The goal is to determine whether those approaches are suited for our internal dataset composed of single animal videos and count per video.

Goals:

- (Work Package 1) Research the latest state-of-the-art methods for pose estimation of lab animals, such as DeepLabCut [1] or Lightning Pose [5], with a focus on mice and single animal videos.
- (Work Packages 2-3). Implement and compare at least 2 state-of-the-art pose estimation methods on open source and private datasets.
- (Work Package 3) Research which preprocessing methods we would have to implement for our type of mice videos.
- (Work Package 4) Use output of pose estimation models to predict pain-related behaviour on our dataset.
- 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 Pose estimation from 2015 – 2024 (e.g. DeepLabcut [1]) using Prisma method
  - Select 3 open-source Datasets for pose estimation of that are similar to ours (single animal videos with a focus on the paw)
- **Work Package 2 – Pose Estimation:**
  - Comparing at least two state-of-the-art pose estimation methods (including DeepLabCut [1]) on the chosen datasets
- **Work Package 3 – Pose Estimation of the affected paw on our dataset:**
  - Test preprocessing methods if needed
  - Study potential dataset bias (e.g. mouse color)
  - Adapt the pose estimation method(s) on our dataset
- **Work Package 4 – Classification on our dataset:**
  - If necessary, label some videos according to pain related behaviour
  - Use the output vectors of the pose estimation of the affected paw to train supervised machine learning model to recognize pain related behaviour
  - Compare at least two machine learning methods

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.

Advisors: Dr. Emmanuelle Salin, Arijana Bohr M. Sc., Prof. Dr. Bjoern Eskofier
Student: Kai Zhao
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References

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[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/
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[4] 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.
[5] Biderman, D., Whiteway, M.R., Hurwitz, C., Greenspan, N., Lee, R.S., Vishnubhotla, A., Warren, R., Pedraja, F., Noone, D., Schartner, M.M. and Huntenburg, J.M., 2024. Lightning Pose: improved animal pose estimation via semi-supervised learning, Bayesian ensembling and cloud-native open-source tools. *Nature Methods*, *21*(7), pp.1316-1328.
[6] Wiltschko, A.B., Johnson, M.J., Iurilli, G., Peterson, R.E., Katon, J.M., Pashkovski, S.L., Abraira, V.E., Adams, R.P. and Datta, S.R., 2015. Mapping sub-second structure in mouse behavior. *Neuron*, *88*(6), pp.1121-1135.
[7] Pereira, T.D., Aldarondo, D.E., Willmore, L., Kislin, M., Wang, S.S.H., Murthy, M. and Shaevitz, J.W., 2019. Fast animal pose estimation using deep neural networks. *Nature methods*, *16*(1), pp.117-125.