Accuracy of DeepLabCut Machine Learning To Markerlessly Track Foot Position During Skilled Walking

Lake, R[1]., Adamczyk, N[1]., Blackwell, A.A[1]., Osterlund, J.R[1]., Segismundo, A[2]., Foecking, E[2,3]., Hastings, P[4]., Wallace, D.G.[1]

[1]Department of Psychology, Northern Illinois University
[2]Department of Veterans Affairs, Edward Hines, Jr. VA Hospital
[3]Department of Otolaryngology, Loyola University Chicago
[4]School of Computing, DePaul University

Introduction

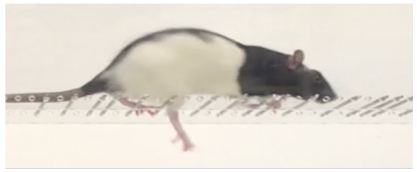
Spontaneously occurring behaviors afford a unique opportunity for the assessment of rodent-based models of neurological disorders; however, quantifying the organization of these behaviors is locked behind time intensive scoring techniques. For example, the performance of rats on the rung walking task depends on sensorimotor function and has been shown to indicate damage localized to cortical and subcortical structures. Scoring performance on the rung walking task involves frame-by-frame detection of foot slips of varying magnitude. Machine learning architectures have shown promise in affording markerless tracking of an animal's body while in motion and may provide novel characterization of behavior on the rung walking task. The current study examines the accuracy of a DeepLabCut machine learning algorithm to accurately track foot position as rats performed the rung walking task. The DeepLabCut machine learning algorithm was trained with subsets of digitized frames. The trained network was then used to digitize the remaining frames. The resulting topographic data of foot position was compared to manually tracked videos. Preliminary analysis has supported the accuracy of DeepLabCut in identifying movement topography. Provided that machine learning accurately tracks foot position, this approach will be used to investigate other brain and behavior relationships that may influence movement organization.

Methods

The rung walking apparatus is a horizontal ladder apparatus (3m) with varying spaced metal rungs (3mm diameter) surrounded by two clear Plexiglas® side walls. The apparatus is suspended 30cm above a ground surface in a well-lit room with a dark refuge cage located at the finishing platform. At the beginning of the task, rats are placed on the start platform and walk along the rungs in one direction to enter the refuge. Between trials, the apparatus is rotated to maintain the variety of rung spacing to prevent learning. Video footage is captured at a slight ventral angle to record all limbs simultaneously.

Rung walking footage from four rats was analyzed and compared for consistency between manual scoring using Tracker software and machine scoring using DeepLabCut. Manual data analysis consisted of an experimenter scoring the X and Y locations of each forelimb, hindlimb, and velocity as the rat moved along the rung walking apparatus. A portion of this data was provided to the DeepLabCut program to facilitate training of the machine learning algorithm on image recognition, while the remaining data was fed through the program as a generalization test to evaluate the accuracy of limb recognition in new footage. The resulting X and Y limb coordinates were compared to manually scored data to assess the accuracy and viability of machine learning in digitizing spontaneous animal behavior.

Figure 1- Photograph of a right hindlimb slip.



Results

Figure 2 – Work flow diagram is presented for DeepLabCut machine learning motion capture software.

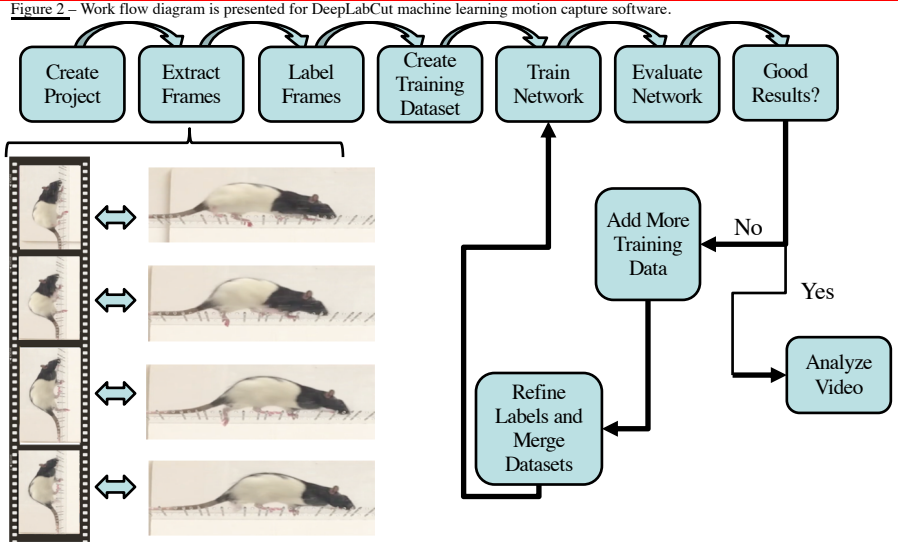


Figure 3 – This illustration depicts the machine learning algorithm learning from digitized examples and applying it on a whole frame.

Figure 4 – Forelimb (top panels) and hind limb (bottom panels) y-coordinate data are presented from the manually scored tracker program and DeepLabCut network for each foot.

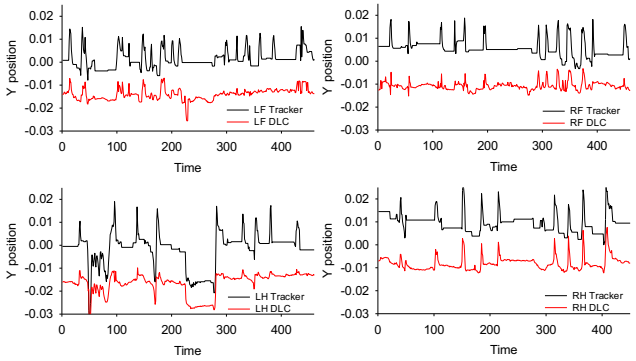


Figure 5 – Correlations between manual tracker and DeepLabCut programs are plotted for y-coordinates obtained from each limb.

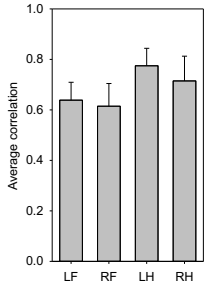


Figure 6– Forelimb (top panels) and hind limb (bottom panels) x-coordinate data are presented from the manually scored Tracker and DeepLabCut network for each foot.

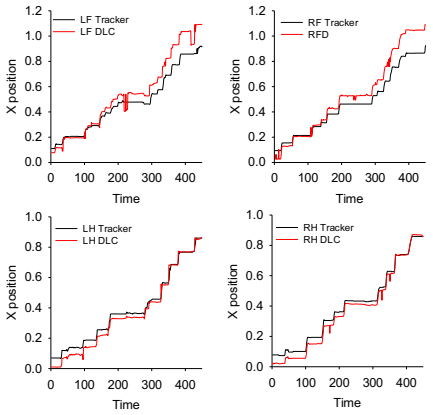
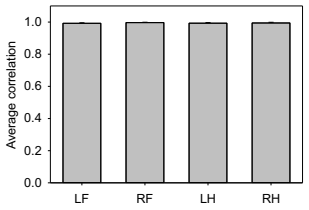


Figure 7 – Correlations between manual Tracker and DeepLabCut programs are plotted for x-coordinates obtained from each limb.



Conclusions

- DeepLabCut accurately tracks the feet of the rat on the rung walking apparatus, supporting its viability in quantifying spontaneous animal behavior.
- This approach provides a more rich description of performance than the traditional qualitative slip analysis.
- This project establishes a foundation for future work investigating the effects of animal models of neurological disorders on the organization of spontaneously occurring behaviors.

References

Mathis, A., Mamidanna, P., Cury, K. M., Abe, T., Murthy, V. N., Mathis, M. W., & Bethge, M. (2018). *DeepLabCut: markerless pose estimation of user-defined body parts with deep learning*(p. 1). Nature Publishing Group.

Jamnia, N., Urban, J. H., Stutzmann, G. E., Chiren, S. G., Reisenbigler, E., Marr, R., ... & Kozlowski, D. A. (2017). A clinically relevant closed-head model of single and repeat concussive injury in the adult rat using a controlled cortical impact device. *Journal of neurotrauma*, *34*(7), 1351-1363.

Metz, G. A., & Whishaw, I. Q. (2002). Cortical and subcortical lesions impair skilled walking in the ladder rung walking test: a new task to evaluate fore-and hindlimb stepping, placing, and co-ordination. *Journal of neuroscience methods*, *115*(2), 169-179.

Please contact Dr. Doug Wallace at dwallace@niu.edu with any questions.