3D Modeling of Running Rodents Based on Direct Linear Transform

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How animals, including humans, are moving has been a grand challenge for modern science that has a direct impact on our health and wellbeing. It can provide a wealth of information to explain the biological world, and to treat human and animal disease. In addition, it can guide us to improve prosthetic limb design or legged robots [1], [2].

Object segmentation and tracking has been challenging in different fields [3], [4], [5], [6]. For tracking of rodents, manual clicking can be considered as the standard method to track landmarks on the body of rodents. However, we have developed semi-automatic and automatic methods to segment and track these landmarks [7], [8], [9].

To study the posture of rodents including roll, pitch, and yaw, it is beneficiary to have a 3D recon- struction of movement [10]. Homography or direct linear transform (DLT) can be employed to generate a 3D projection using 2D images captured from different angles [6], [11]. Here, we present a 3D model generated from running rodents on a treadmill.

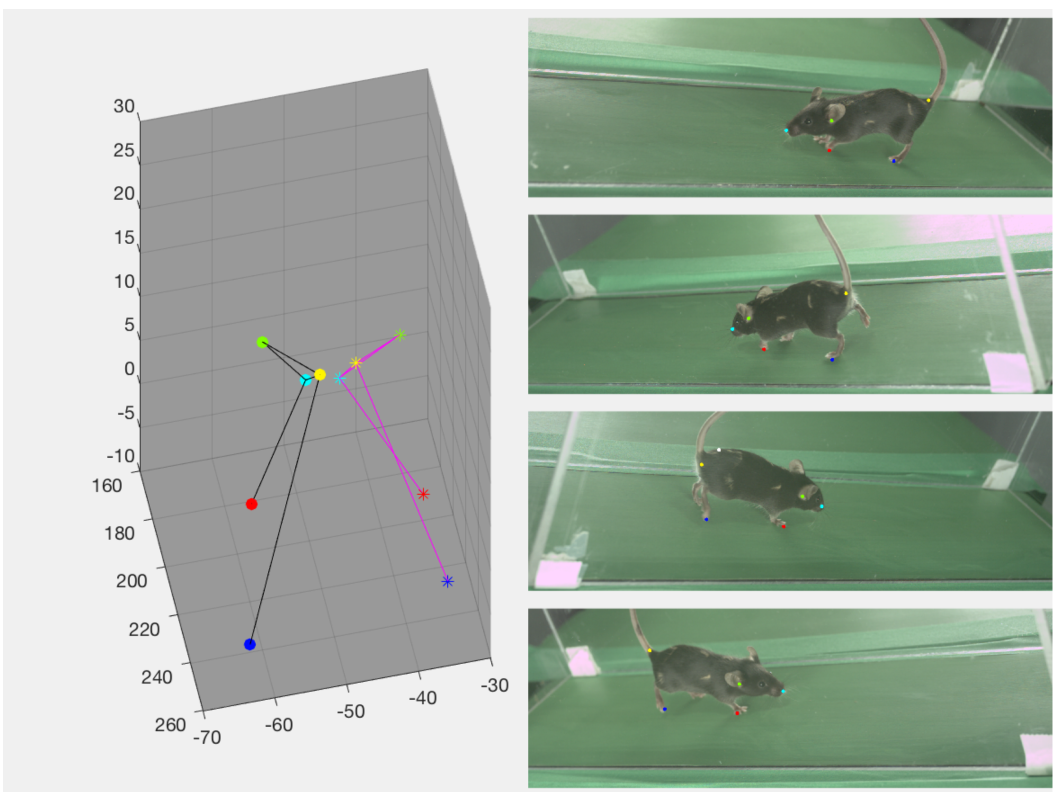

Fig. 1: This graph shows the interference capacitance of three cuffs calculated for different frequencies. Each of the cuffs was measured three times and the error bars show the related changes for repetition of measurements.

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The proposed method in [8] was used to track the paws and a landmark tracker was applied on the frames to track other landmarks (nose, ear, and tail) [9].

A calibration object was used to calculate the DLT coefficients using a Matlab toolbox provided by the Hedrick Lab [11]. Then, the coordinates of landmarks tracked in the image planes were projected to the 3D domain and remapped to the 2D image planes to evaluate the accuracy of this transform. In addition, the landmarks were linked to each other on the 3D domain to generate a 3D model of rodents. This model is illustrated on Fig.1.

The presented method was evaluated using 400 frames captured from each of four cameras located on sides as presented in [8]. The common method to evaluate the 3D projection is finding some object with a known shape. This was done using a calibration object having 25 markers to calibrate the whole treadmill volume. The average error of the DLT mapping for the calibration object was 1.75 with a standard deviation of 0.49 pixels. This number shows how far the markers were transferred to 3D and remapped to 2D. we calculated the same error for the tracked landmarks. The error had an average of 3.59 with a standard deviation of 1.12 pixels. In addition to this quantification, a 3D model of rodent was generated by linking five landmarks (nose, ear, two paws, and tail) on each side and it visually seems to be a reliable 3D reconstruction as a sample 3D modeling is illustrated in Fig.1.

A method was presented to generate the 3D model of running rodents on the treadmill. We used two methods [8], [9] to track the five landmarks on each side of an animal. The results showed the main difficulty was for correlating the tracked landmarks from two cameras; however, the results showed a promising 3D reconstruction. The model presented here can help for advanced tracking systems and studies related to the posture of rodents. We will try to use deep learning to develop the tracking method [12].

REFERENCES

[1] S. Cirak, V. Arechavala-Gomeza, M. Guglieri, L. Feng, S. Torelli, K. Anthony, S. Abbs, M. E. Garralda, J. Bourke, D. J. Wells et al., "Exon skipping and dystrophin restoration in patients with duchenne muscular dystrophy after systemic phosphorodiamidate morpholino oligomer treatment: an open-label, phase 2, dose-escalation study," The Lancet, vol. 378, no. 9791, pp. 595–605, 2011.

[2] H. M. Herr and A. M. Grabowski, "Bionic ankle–foot prosthesis normalizes walking gait for persons with leg amputation," in Proc. R. Soc. B, vol. 279, no. 1728. The Royal Society, 2012, pp. 457–464.

[3] S. Minaee and Y. Wang, "Screen content image segmentation using robust regression and sparse decomposition," IEEE Journal on Emerging and Selected Topics in Circuits and Systems, vol. 6, no. 4, pp. 573–584, 2016.

[4] R. Penjweini, S. Deville, O. Haji Maghsoudi, K. Notelaers, A. Ethirajan, and M. Ameloot, "Investigating the effect of poly-l-lactic acid nanoparticles carrying hypericin on the flow-biased diffusive motion of hela cell organelles," Journal of Pharmacy and Pharmacology, 2017.

[5] O. H. Maghsoudi, M. Alizadeh, and M. Mirmomen, "A computer aided method to detect bleeding, tumor, and disease regions in wireless capsule endoscopy," in Signal Processing in Medicine and Biology Symposium (SPMB), 2016 IEEE. IEEE, 2016, pp. 1–6.

[6] S. Benhimane and E. Malis, "Homography-based 2d visual tracking and servoing," The International Journal of Robotics Research, vol. 26, no. 7, pp. 661–676, 2007.

[7] O. H. Maghsoudi, A. V. Tabrizi, B. Robertson, P. Shamble, and A. Spence, "A novel automatic method to track the body and paws of running mice in high speed video," in Signal Processing in Medicine and Biology Symposium (SPMB), 2015
IEEE. IEEE, 2015, pp. 1–2.

[8] O. Haji Maghsoudi, A. V. Tabrizi, B. Robertson, P. Shamble, and A. Spence, "A rodent paw tracker using support vector machine," in *Signal Processing in Medicine and Biology Symposium (SPMB), 2016 IEEE*. IEEE, 2016, pp. 1–3.

[9] O. Haji Maghsoudi, A. V. Tabrizi, B. Robertson, and A. Spence, “Superpixels based marker tracking vs. hue thresholding in rodent biomechanics application,” in The 51st Asilomar Conference on Signals, Systems and Computers. IEEE, 2017.
[10] A. A. Migliaccio, R. Meierhofer, and C. C. Della Santina, “Characterization of the 3d angular vestibulo-ocular reflex in c57bl6 mice,” Experimental brain research, vol. 210, no. 3-4, pp. 489–501, 2011.
[11] T. L. Hedrick, “Software techniques for two-and three-dimensional kinematic measurements of biological and biomimetic systems,” Bioinspiration & biomimetics, vol. 3, no. 3, p. 034001, 2008.
[12] S. Minaee, A. Abdolrashidiy, and Y. Wang, “An experimental study of deep convolutional features for iris recognition,” in Signal Processing in Medicine and Biology Symposium (SPMB), 2016 IEEE. pp. 1–6.

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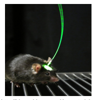
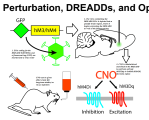
Background

- Examining locomotion and study animal kinematics
- Why Mice/Rats?
- Perturbation, DREADDs, and Optogenetics



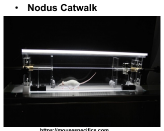
http://blog.addgene.org/the-materials-science-of-optogenetics-experiments



https://neurwitted.org/2016/01/28/dawn-of-the-dreadd/

- Using high speed multi-camera system
- Available systems:
  - Digigait
  - Motorater
  - Nodus Catwalk

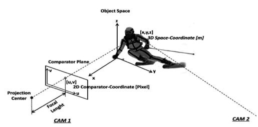
http://www.noldus.com/animal-behavior-research/products/catwalk



https://mousespecifics.com

http://animalab.eu/products/motorater

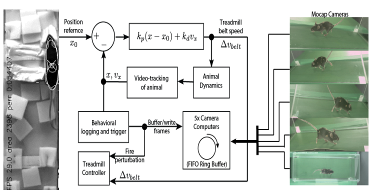
- 3D Reconstruction



https://goo.gl/images/REjCZH

Camera and Treadmill Setup

- Video data were gathered at 250 frames per second with a resolution of 2048×700 pixels.
- 4 Sec * 250 Frames = 1 Trial, 100-1000 Trials = 1 Experiment

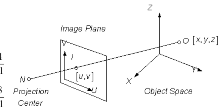


Method

- Direct Linear Transformation

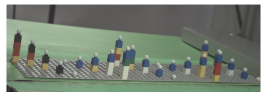
$$U1 = \frac{L1X + L2Y + L3Z + L4}{L9X + L10Y + L11Z + 1}$$

$$U2 = \frac{L5X + L6Y + L7Z + L8}{L9X + L10Y + L11Z + 1}$$



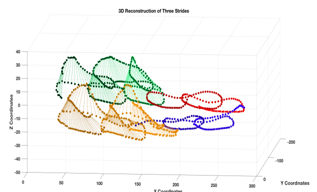
http://www.kwon3d.com/theory/dlt/dlt.html

- Calibration



Results

- The average error of the DLT mapping for the calibration object was 1.75 with a standard deviation of 0.49 pixels.
- This number shows how far the markers were transferred to 3D and remapped to 2D.
- The calculated error for the tracked landmarks was 3.59 with a standard deviation of 1.12 pixels.
- Making Model



Maghsoudi, Omid Haji, et al. "Superpixels based marker tracking vs. hue thresholding in rodent biomechanics application." *arXiv preprint arXiv:1710.06473* (2017).

Limitations

- Needs Tracking
- Calibration needed if cameras moving

Advantages

- Helping to fix mistakes for tracking
- Adding more dimensions to bioemcahnics, biology, and neuroscience studies

Acknowledgements

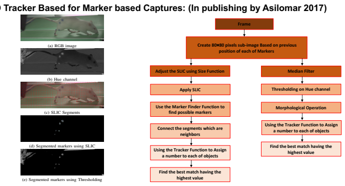
This material is based upon work supported by the U. S. Army Research Laboratory and the U. S. Army Research Office under contract/grant number 64929EG to A.J. Spence.

References

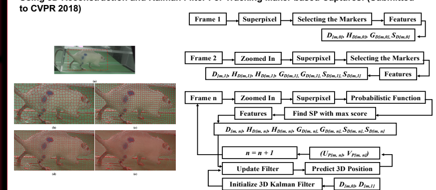
1) O. H. Maghsoudi, A. V. Tabrizi, B. Robertson, P. Shamble, and A. Spence, "A novel automatic method to track the body and paws of running mice in high speed video," in *Signal Processing in Medicine and Biology Symposium (SPMB), 2015 IEEE*. IEEE, 2015, pp. 1–2.
2) Maghsoudi, Omid Haji, et al. "Superpixels based marker tracking vs. hue thresholding in rodent biomechanics application." *arXiv preprint arXiv:1710.06473* (2017).
3) T. L. Hedrick, "Software techniques for two-and three-dimensional kinematic measurements of biological and biomimetic systems," *Bioin- spiration & biomimetics*, vol. 3, no. 3, p. 034001, 2008.
4) R. Achanta, A. Shaji, K. Smith, A. Lucchi, P. Fua, and S. Susstrunk, "Slic superpixels compared to state-of-the-art superpixel methods," *IEEE transactions on pattern analysis and machine intelligence*, vol. 34, no. 11, pp. 2274–2282, 2012.
5) Přibyl, Bronislav, Pavel Zemčík, and Martin Čadík. "Absolute pose estimation from line correspondences using direct linear transformation." *Computer Vision and Image Understanding* (2017).

Future Directions

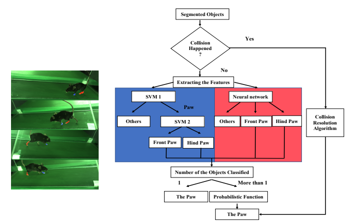
Using 2D Tracker Based for Marker based Captures: (In publishing by Asilomar 2017)



Using 3D Reconstruction and Kalman Filter For Tracking Maker based Captures: (Submitted to CVPR 2018)



Using 2D Tracker Based for Markerless Captures: (Submitted to IET Image Processing)



Using 3D Tracker Based for Markerless Captures: (Under Developing)