Marc Badger

GRASP Laboratory • Levine 403 • 3330 Walnut St. • Philadelphia, PA 19104 • 801.814.2728
mbadger@seas.upenn.edu • www.ocf.berkeley.edu/~badger

EDUCATION

University of California, Berkeley, Berkeley, CA
Ph.D. Integrative Biology 2016

- Dissertation: The Biomechanics of Obstacle Negotiation by Hummingbirds
- Ph.D. advisor: Dr. Robert Dudley
- Computer vision coursework: Computer Vision (J. Malik), Statistical Learning Theory (P. Bartlett), Visual Object and Activity Recognition seminar (T. Darrell and A. Efros)

Harvey Mudd College, Claremont, CA 2010
B.S. in Physics with Honors and Distinction, GPA: 3.7

- Senior Thesis: Improving Targets for Laser Fusion Experiments: Developing an Electrostatic Delivery Device
- Thesis advisor: Dr. Thomas Donnelly

APPOINTMENTS

GRASP lab, University of Pennsylvania, Philadelphia, PA 2019-present
Postdoctoral Researcher, Department of Computer and Information Science

- Topics: Multi-view tracking, animal pose and shape estimation, social interactions and social networks in songbirds
- Advisors: Dr. Kostas Daniilidis (CIS) and Marc Schmidt (Biology)

University of California, Davis, Davis, CA 2017-2019
Postdoctoral Scholar, Department of Neurobiology, Physiology, and Behavior

- Topics: Biomechanics and behavior of maneuvering flight and obstacle avoidance in bees, multi-view pose estimation of bees maneuvering in turbulence
- Advisor: Dr. Stacey Combes

RESEARCH INTERESTS

Animal flight through windy and cluttered environments. Computer vision and deep learning methods for animal tracking, pose estimation, and action recognition. I have an intense passion for creating robotic systems that interact with animals in my experiments and I work to advance our understanding of machine perception by creating deep learning tools that extract useful data from biomechanics videos.

AWARDS AND FELLOWSHIPS

- Team Grants for Interdisciplinary Activities, CURF at UPenn 2020
- NVIDIA GPU Grant 2018
- National Science Foundation Graduate Research Fellowship (awarded 2010) 2012-2015
- Best Student Oral Presentation, Society for Integrative and Comparative Biology 2014
- NSF CiBER-IGERT Traineeship, UC Berkeley 2010-2012
- Integrative Biology Summer Research Fellowship, UC Berkeley 2012-2015
- Tinker Summer Field Research Grant, Center for Latin American Studies, UC Berkeley 2011
- Creative Bicycle Design Project, Shanahan Project Fund, Harvey Mudd College 2007-2009
- National Merit Scholarship Award 2006-2010

PUBLICATIONS

Wang, Y., N. Kolotouros, K. Daniilidis, **M. Badger**. 2021 (*accepted*). Birds of a feather: capturing avian shape models from images. *Computer Vision and Pattern Recognition*.

M. Badger, Y. Wang, A. Modh, A. Perkes, N. Kolotouros, B. Pfrommer, M. Schmidt, and K. Daniilidis. 2020. 3D Bird Reconstruction: a Dataset, Model, and Shape Recovery from a Single View. In: Vedaldi A., Bischof H., Brox T., Frahm JM. (eds) *Computer Vision – ECCV 2020. Lecture Notes in Computer Science*, vol 12363. Springer, Cham. doi.org/10.1007/978-3-030-58523-5_1.

Escalante, I., **M. Badger**, and D. Elias. 2020. Rapid recovery of locomotor performance after leg loss in harvestmen. *Scientific Reports* 10(1): 14747. doi:10.1038/s41598-020-70557-2.

Burnett, N., **M. Badger**, and S. Combes. 2020. Wind and obstacle motion affect honeybee flight strategies in cluttered environments. *Journal of Experimental Biology* 223: jeb222471. doi:10.1242/jeb222471.

Escalante, I., **M. Badger**, and D. Elias. 2019. Variation in movement: multiple locomotor gaits in Neotropical harvestmen. *Biological Journal of the Linnean Society* 127(2): 493-507. doi:10.1093/biolinnean/blz047.

Badger, M., H. Wang, and R. Dudley. 2019. Avoiding topsy-turvy: how Anna's Hummingbirds (*Calypte anna*) fly through upward gusts. *Journal of Experimental Biology* 222: jeb176263. doi:10.1242/jeb.176263.

Ortega-Jimenez, V., **M. Badger**, H. Wang, and R. Dudley. 2016. Into rude air: hummingbird flight performance in variable aerial environments. *Philosophical Transactions of the Royal Society B: Biological Sciences* 371: 20150387. doi:10.1098/rstb.2015.0387.

Badger*, M., V. Ortega-Jimenez*, L. von Rabenau, A. Smiley, and R. Dudley. 2015. Electrostatic charge on flying hummingbirds and its potential role in pollination. *PLOS ONE* 10(9): e0138003. doi:10.1371/journal.pone.0138003. **these authors contributed equally*

Ros, I., **M. Badger**, A. Pierson, L. Bassman, and A. Biewener. 2015. Pigeons produce aerodynamic torques through changes in wing trajectory during low speed aerial turns. *Journal of Experimental Biology* 218: 480-490.

Ros, I., L. Bassman, **M. Badger**, A. Pierson, and A. Biewener. 2011. Pigeons steer like helicopters and generate down- and upstroke lift during low speed turns. *Proceedings of the National Academy of Sciences of the United States of America* 108: 19990-19995.

WORK IN PROGRESS

Badger, M., K. McClain, A. Smiley, J. Ye, and R. Dudley. (*in preparation*). Adaptive shape shifting by hummingbirds enables in-flight aperture negotiation.

TEACHING AND MENTORING EXPERIENCE

Mentor, Team Grants for Interdisciplinary Activities, UPenn 2020

- Developed educational goals, lectures, and material, and led interdisciplinary undergraduate research experiences for two students in Computer Science and two students in Biology on a project using computer vision to track and detect interactions between birds in an outdoor aviary.
- Students performed deep dives, communicated findings to non-expert and expert peers, contributed significant advances to the project, and developed interdisciplinary teaming skills.

TEACHING AND MENTORING EXPERIENCE (*continued*)

Mentor, Undergraduate Research Apprentice Program, UC Berkeley 2012-2016

- My work at UC Berkeley provided interdisciplinary undergraduate research experiences in the lab and field for students interested in biology, physics, computer science, and engineering.
- I have a strong commitment to mentoring students from diverse backgrounds. My group of seven undergraduate mentees at Berkeley included five women and six students who identify with an ethnic minority group.
- Undergraduate researchers who worked with me are now attending graduate programs in Neuroscience at NYU, Integrative Biology at UC Berkeley, and Materials at UC Santa Barbara (with an honorable mention from the NSF GRFP). Another mentee is completing a Doctor of Pharmacy at UT Austin.

Graduate Student Instructor, UC Berkeley Spring 2013, 2016

Mechanics of Organisms Laboratory

- Topics included running kinematics and motor control in cockroaches using EMG, gecko locomotion and bio-inspired designs for fibrillar adhesion, and muscle performance using the work-loop technique in cockroaches.
- Student Reviews: 7/7 overall teaching effectiveness. "**One of the most engaging and instructional courses in my undergrad schooling. Marc was a wonderful communicator and collaborator in lab**." "Enthusiastic and a great explainer!" "Pushed us to think critically. Taught research skills that we got to apply to discover new things." "He was a great GSI! He is a great budding teacher." "Very knowledgeable and friendly. Made class fun and explained concepts clearly." "Great educational value – the best class at Cal! Engaging, building of teamwork, knowledge, and research." "This class really taught me how to do quality research in a group setting."

Bioinspired Design

- Taught students to decompose discoveries communicated by primary biology literature, extract enabling mechanisms and principles from biological discoveries, propose additional experiments to needed to apply principles in new areas, and translate these ideas into novel designs with important societal impact.
- Student Reviews: 6/7 overall teaching effectiveness. "Instructors and GSIs were very motivated, helpful, and always willing to help out the students. They were very invested in making sure the students got all the help they needed and were always accessible." "I personally enjoyed Marc Badger's presentations, his flow, and the way he presented the lessons." "Marc was great! He was charismatic and as helpful as could be. I wish he talked more about how his work related to bio-inspired design."

Advised independent undergraduate research project Fall 2012

- Investigated landing behavior in hummingbirds
- Research presented by undergraduate students as a poster at the Society for Integrative and Comparative Biology Annual Meeting in San Francisco, CA in January 2013.

Academic Excellence Facilitator, Harvey Mudd College 2008-2010

- Facilitated physics homework and review sessions for students
- Developed weekly workshops for improving pedagogical and communication techniques

MEETING PRESENTATIONS *(* denotes presenting author*)

Burnett, N.*, **M. Badger**, and S. Combes. 2021. Shooting the gap: how bees protect their wings in windy, dynamic obstacle courses. Society for Integrative and Comparative Biology Annual Meeting, Austin, TX.

Badger, M.*, A. Perkes, B. Pfrommer, Y. Wang, A. Modh, K. Daniilidis, and M. Schmidt. 2020. From moments to months: Multi-timescale tracking and analysis of songbird social interactions in a smart aviary. Society for Integrative and Comparative Biology Annual Meeting, Austin, TX, oral presentation.

Burnett, N.*, **M. Badger**, and S. Combes. 2020. Wind and canopy height affect honey bee flight performance in cluttered environments. Society for Integrative and Comparative Biology Annual Meeting, Austin, TX.

Bucher, B.*, A. Arapin, R. Sekar, F. Duan, **M. Badger**, K. Daniilidis, and O. Rybkin. 2019. Perception-Driven Curiosity with Bayesian Surprise. RSS Workshop on Combining Learning and Reasoning for Human-Level Robot Intelligence, Freiburg, Germany.

MEETING PRESENTATIONS *(continued)*

Badger, M.* and S. Combes. 2019. MegaTracks: Deep learning methods enable rapid, automated tracking of complex motion sequences. Society for Integrative and Comparative Biology Annual Meeting, Tampa, FL, oral presentation.

Burnett, N.*, **M. Badger**, and S. Combes. 2019. Flight planning on the wing: Honeybees assess obstacle motion from afar before deciding to land on or pass through wind-blown clutter. Society for Integrative and Comparative Biology Annual Meeting, Tampa, FL.

Combes. S.*, **M. Badger**, S. Gagliardi, A. Wargin^{U}, and M. Flores^{U}. 2019. Inferring real-world flight conditions from high-throughput preference tests: bumblebees display partiality for particular features of wind and clutter. Society for Integrative and Comparative Biology Annual Meeting, Tampa, FL.

Badger, M.*, U. Chang, and S. Combes. 2018. Down in the mouth: consequences of mandible-loading for flight stability in blue orchard bees (*Osmia lignaria*). Society for Integrative and Comparative Biology Annual Meeting, San Francisco, CA, oral presentation.

Badger, M.*, H. Wang, and R. Dudley. 2016. Avoiding topsy-turvy: how Anna's Hummingbirds (*Calypte anna*) fly through upward gusts. Society for Integrative and Comparative Biology Annual Meeting, Portland, OR, oral presentation.

Escalante, I.* **M. Badger**, and D. Elias. 2016. Compensatory behaviors in locomotion performance induced by autotomy in Daddy Long-legs. Society for Integrative and Comparative Biology Annual Meeting, Portland, OR.

Louis, L.*, **M. Badger**, and R. Dudley. 2016. It's a breeze: aperture negotiation by hummingbirds flying with and against the wind. Society for Integrative and Comparative Biology Annual Meeting, Portland, OR.

Badger, M.*, A. Smiley, J. Ye, K. McClain, and R. Dudley. 2014. Shape-shifting through apertures: kinematic strategies and correlated flight metrics in Anna's Hummingbirds (*Calypte anna*). Society for Integrative and Comparative Biology Annual Meeting, Austin, TX. ***Best Student Oral Presentation*.**

Badger, M.* and M. Jones. 2012. Falling faster: Size and folding behavior decrease descent time in a brittle star (*Ophiocoma aethiops*). Society for Integrative and Comparative Biology Annual Meeting, Charleston, SC, poster.

Ros, I.*, **M. Badger,** A. Pierson, L. Bassman and A. Biewener. 2011. Translational and rotational components of low speed turning in the pigeon *Columba livia*. Society for Integrative and Comparative Biology Annual Meeting, Salt Lake City, UT.

Badger, M.* and S. Adolph. 2010. Imperfect detection, lag times and the evolution of phenotypic plasticity. Society for Integrative and Comparative Biology Annual Meeting, Seattle, WA, poster.

Badger, M.* and S. Adolph. 2010. Thermal sensitivity of sprint speed in a spiny lizard. Presentation Days 2010: A Celebration of Student Projects, Harvey Mudd College, Claremont, CA, oral presentation.

Badger, M.*, A. Pierson* and L. Bassman. 2010. Quantifying the effect of body configuration changes on orientation in the maneuvering flight of a pigeon. Presentation Days 2010: A Celebration of Student Projects, Harvey Mudd College, Claremont, CA, poster.

Badger, M.* and T. Donnelly. 2010. Developing an electrostatic levitation device: a novel system for delivering microspheres to the focus of a laser pulse. Presentation Days 2010: A Celebration of Student Projects, Harvey Mudd College, Claremont, CA, oral presentation.

Adolph, S.* and **M. Badger**. 2007. Testing for temperature trade-offs in lizards. Society for Integrative and Comparative Biology Annual Meeting, Phoenix, AZ.

Badger, M.* and S. Adolph. 2007. Testing for trade-offs in temperature tolerance of lizards. Southern California Conference for Undergraduate Research, Los Angeles, CA, oral presentation.

TRAINING AND OTHER RESEARCH EXPERIENCE

Summer Institute for Preparing Future Faculty, University of California, Berkeley 2015

- Participated as an Institute Fellow in two six-week courses: From Graduate Student to Faculty Member and Editing, Academic Writing, and Academic Publishing

Organization for Tropical Studies, Costa Rica 2011

Tropical Biology: An Ecological Approach

- Designed and performed studies at 9 field stations in Costa Rica investigating plant and animal spatial distributions, territory defense, navigation, and escape responses.

INVITED DEPARTMENTAL AND PUBLIC SEMINARS

CV4Animals: Computer Vision for Animal Behavior Tracking and Modeling Workshop, CVPR 2021
Animal Behavior Graduate Group, University of California, Davis, January 2019
Koditschek lab group, University of Pennsylvania, May 2018
Department of Mathematics, Weber State University, March 2017
Department of Biology, Harvey Mudd College, March 2014
Berkeley Edge Conference, UC Berkeley Interdisciplinary Centers Panel Discussion, 2012
Convocation ceremony, Harvey Mudd College, Claremont, CA, 2009
Decemberfest, Harvey Mudd College, Claremont, CA. 2007, 2008.

- Presented original research to 50 high school counselors and described student research at Harvey Mudd College