Core Faculty Profile

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Research Interests

- Quantification and modeling of biomechanical capacity and its relationship to sensory function
- Reconstruction of neural input during natural behaviors
- Positioning of sensory surfaces during signal acquisition
- Development of robotic models of animal locomotion and sensing

The interplay of biomechanics and the nervous system: neuromechanics, neuroethology, robotics, and simulation, using weakly electric fish as a model system. One way to view an animal is that it represents an answer to the question: "What's out there that's relevant to my fitness, and how do I get there to acquire those resources?" There is both the informational, or sensory problem of detecting and assessing these resources, and the mechanical problem of moving to the resource, such as food or a mate. The research in my group is dedicated to understanding fundamental problems of how an animal's biomechanics relates to the animal's informational needs, particularly how to solve the problem of moving through space towards a target of interest while simultaneously increasing the quality of the information extracted from the biosensor arrays on the body surface. We are engaged in both a basic science understanding of these mechanisms, and applying the knowledge gained for the development of new technology, such as novel locomotor and sensory devices, where the integration of movement control and sensing is of key importance.

One recent result helps illustrate our research interests. Analysis of reconstructed electrosensory stimuli associated with prey capture behavior of weakly electric fish revealed an omnidirectional sensing volume surrounding the body. Analysis of the small time reachable volume, a concept from control theory, revealed a similarly shaped locomotor volume that reflects the unusual maneuverability and backwards-swimming capabilities of these animals. The locomotor volume is nearly congruent to the prey sensing volume when evaluated over a time interval corresponding to the sum of the sensorimotor delay time and the braking time. This strongly suggests that biomechanical capacity and neural function are deeply interconnected. More advanced vertebrates such as mammals and birds appear to have sensing volumes that far exceed the size of their small-time locomotor volume, which may enable the execution of sequences of strategic movements (such as stalking a target) versus reactive control strategies. The degree of overlap between sensing and locomotor volumes, and their relative magnitudes, is likely to have fundamental impact on the structure and function of associated neural control circuits. Analogous issues arise in the design of autonomous robots, where reactive controllers are used to control motion within the stopping distance of the robot, utilizing fast proximity sensors, while switching controllers or planners utilizing slower sensors and more complex analysis of sensory signals are used to control motion over larger temporal and spatial scales.

Selected Publications

1. MacIver, M.A., Snyder, J.B., Nelson, M.E., Burdick, J. W. The Coupling of Sensory and Movement Volumes in an Active Sensing System. Submitted.
2. MacIver, M.A. Neuroethology: From Morphological Computation to Planning. The Cambridge Handbook of Situated Cognition, Robbins P. & Aydede, M. (eds). Cambridge University Press. In press.
3. James R. Solberg, Kevin M. Lynch, Malcolm A. MacIver (2007) Robotic Electrolocation: Active Underwater Target Localization with Electric Fields. Proceedings of the 2007 International Conference on Robotics and Automation (ICRA), Rome, Italy.
4. Epstein, M., Colgate, J.E, MacIver, M.A. (2005) A Biologically Inspired Robotic Ribbon Fin. Proceedings of the 2005 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), workshop on Morphology, Control, and Passive Dynamics.
5. Epstein, M., Colgate, J.E, MacIver, M.A. (2006) Generating Thrust with a Biologically-Inspired Robotic Ribbon Fin Source. Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) Beijing, China.
6. MacIver, M.A., Fontaine, E., Burdick, J. W. (2004) Designing future underwater vehicles: principles and mechanisms of the weakly electric fish. IEEE Journal of Oceanic Engineering 29(3):651-659.
7. Nelson, M.E. and MacIver, M.A. (2006) Sensory acquisition in active sensing systems. Journal of Comparative Physiology A 192: 573-586.
8. Nelson, M. E., M. A. MacIver, and S. S. Coombs (2002). Modeling electrosensory and mechanosensory images during the predatory behavior of weakly electric fish. Brain, Behavior, and Evolution 59(4):199-210.
9. MacIver, M. A. and M. E. Nelson (2001). Towards a biorobotic electrosensory system. Autonomous Robots 11(3): 263-266.
10. MacIver, M. A. (2001). How building physical models can reduce and guide the abstraction of nature. Behavioral and Brain Sciences 24(6): 1066-1067.
11. MacIver, M. A., N. M. Sharabash, and M. E. Nelson (2001). Prey-capture behavior in gymnotid electric fish: Motion analysis and effects of water conductivity. Journal of Experimental Biology 204(3): 543-557.
12. MacIver, M. A. and M. E. Nelson (2000). Body modeling and model-based tracking for neuroethology. Journal of Neuroscience Methods 95(2): 133-143.
13. Nelson, M. E. and M. A. MacIver (1999). Prey capture in the weakly electric fish Apteronotus albifrons: Sensory acquisition strategies and electrosensory consequences. Journal of Experimental Biology 202(10): 1195-1203.

Selected Presentations, 2006 - 2007

2007

1. Infomechanical specializations for maximizing prey capture in knifefish. University of British Columbia, Vancouver, Canada, July 21 2007. Electrosensory Systems Satellite Meeting, 8th International Congress of Neuroethology.
2. How having a Buena Vista gives you the ability to plan for it. University of British Columbia, Vancouver, Canada, July 23, 2007. 8th International Congress of Neuroethology, Symposium on Top Down Influences in Active Sensing.
3. Robotic Electrolocation: Active Underwater Target Localization with Electric Fields. Angelicum University, Rome Italy, April 13 2007. Presented by James Solberg. 2007 IEEE International Conference on Robotics and Automation, Session on Bio-inspired Perception.
4. Embodiment, control, and cognition: A fish eye's view from neuroethology. Johns Hopkins University, Baltimore, Maryland, USA, March 1 2007. The Department of Mechanical Engineering.
5. Embodiment, control, and cognition: A fish eye's view from neuroethology. University of Maryland, College Park, Maryland, USA, February 16 2007. The Program in Neuroscience and Cognitive Science.

2006

1. Embodiment, control, and cognition. Cornell University, Ithaca, NY, USA Nov 30, 2006. Machines and Organisms Seminar Series, Nonlinear Systems IGERT.
2. Towards Direct Numerical Simulation of Freely Swimming Fish, by Oscar M. Curet,

Neelesh A. Patankar, and Malcolm A. MacIver. Presented by Oscar M. Curet. American Physical Society, Division of Fluid Dynamics, 59th Annual Meeting, Tampa FL, USA, Nov 19, 2006. Session AA: Biofluid Dynamics 1: Swimming-1.
3. Hydrodynamics of ribbon fin-based swimming with application to highly maneuverable underwater vehicles, by Neelesh A. Patankar, Oscar M. Curet, and Malcolm A. MacIver. Presented by Neelesh A. Patankar. American Physical Society, Division of Fluid Dynamics, 59th Annual Meeting, Tampa FL, USA, Nov 19, 2006. Session AA: Biofluid Dynamics 1: Swimming-1.
4. Spatial congruence of sensation and action: a general design principle for active sensing? Chicago IL, USA, Sept 22, 2006. Northwestern University, Department of Physiology.
5. Generating Thrust with a Biologically-Inspired Robotic Ribbon Fin, by Michael Epstein, J. Edward Colgate, and Malcolm A. MacIver. Presented by Malcolm A. MacIver. Beijing, China, October 10, 2006. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), session on robotic fish.
6. Embodiment, control, and cognition. Marine Biological Laboratory, Woods Hole, MA, USA June 19, 2006. Neural Systems and Behavior Course, Evening lecture program.
7. Neuroethology: From Morphological Computation to Planning. University of Chicago, Feb 24, 2006. The Department of Philosophy, John Haugeland and William Wimsatt's graduate seminar on boundaries and modules.

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