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**EDUCATION**

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2001 PhD Neuroscience, University of Illinois and the Beckman Institute of Advanced Science and Technology, Urbana IL  
1996 Course work only of dual Ph.D. in cognitive science and philosophy, Indiana University, Bloomington IN  
1992 MA Philosophy, University of Toronto  
1991 BSc Double major in computer science and philosophy, University of Toronto, graduated with High Distinction  
1986 AEE Electrical Engineering Technician, Confederation College, Thunder Bay, Ontario Canada

**PROFESSIONAL EXPERIENCE**

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2016-present Professor (Joint between Dept. of Mechanical Engineering & Dept. of Biomedical Engineering), and Dept. of Neurobiology by Courtesy, Northwestern University  
2010-2016 Associate Professor (Joint between Dept. of Mechanical Engineering & Dept. of Biomedical Engineering), and Dept. of Neurobiology by Courtesy, Northwestern University  
2003-2010 Assistant Professor (Joint between Dept. of Mechanical Engineering & Dept. of Biomedical Engineering), and Dept. of Neurobiology by Courtesy, Northwestern University  
2001-2003 Postdoctoral Fellow, Division of Engineering and Applied Science, Computation and Neural Systems Program, and Center for Neuromorphic Systems Engineering, California Institute of Technology, Pasadena CA

**HONORS AND AWARDS**

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2014 Symposium speaker for American Association for the Advancement of Science session on biologically inspired robotics, Chicago IL

- 2014 Plenary Speaker at the International Congress of Neuroethology, August 2014, Sapporo Japan.
- 2013 TEDx Caltech “The Brain” closing speaker, “Can We Expand Our Consciousness with Neuroprosthetics?” Jan 18, 2013.
- 2009 Received Presidential Early Career Award for Science and Engineering from Barack Obama at the White House
- 2009 Recipient, National Science Foundation CAREER Award
- 2006 Invited Distinguished Evening Lecturer, MBL at Woods Hole Summer Course in Neural Systems and Behavior
- 2003 Invited Panelist, *Issues at the Intersection of Art and Science*, Center for Neuromorphic Systems Engineering at Caltech and the Art Center's Alyce de Roulet Williamson Gallery, Pasadena CA
- 2003 Recipient, Center for Neuromorphic Systems Engineering NEURO Art Installation Development Award for **Body Electric**
- 1999 Selected to attend the Telluride Neuromorphic Engineering Workshop
- 1997 Beckman Institute for Advanced Science and Technology Research Assistantship
- 1995 Scholarship to Attend the Princeton Lectures on Biophysics
- 1994 McDonnell Summer Institute in Cognitive Neuroscience Scholarship
- 1993 Cognitive Science Summer Research Fellowship, Indiana University
- 1992 Summer internship, Artificial Intelligence, Canadian National Research Council  
*Developed automatic natural language explanations of military jet engine faults*
- 2001 Best Exhibit, Beckman Institute for Advanced Science Open House
- 1991 Graduated with High Distinction (University-wide graduating class GPA Award)

## CORE AREAS OF INTEREST

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**The mechanical basis of information harvesting in animals.** The analysis of the metabolic cost of information for animals has proven to be a useful approach to understanding a variety of patterns within neuronal systems. These analyses have uncovered a host of ways that nervous systems reduce their energetic footprint. A missing piece of the puzzle, however, is that animals frequently move in order to obtain better sensory information. Thus an analysis of the energetics of neurons needs to be complemented by an analysis of the energetics of movement related to improving signal. To that end, we have developed a novel way to characterize the “motor range”—analogous to sensory range—of an animal based on concepts from nonlinear control engineering. Using this concept, we have shown that a unique feature of active sensing animals is that they sense in a “just-in-time” fashion, such that if they sensed at a shorter range, they would collide with their target. For active sensing animals like bats, dolphins, and electric fish, sensing at a longer range is made extremely expensive by quadratic signal loss in each direction, outbound to target and return, or fourth power of distance in total. The consequence of sensing with a narrow margin for maneuvering is a body which has exceptional agility, as these animals need to be able to change direction rapidly to start approaching their target following detection. We have documented a host of motor system adaptations that make such agility possible while still maintaining stability. We’ve shown that behavior which appears suboptimal from a purely

locomotory or sensory acquisition perspective is optimal when examined together: animals do not optimize for movement or sensing alone, but for movement which minimizes locomotory energy needed for each sensory target, such as prey, acquired. Hyperlinks to relevant work: [J25](#), [C09](#), [J14](#), [J08](#). [Video explaining ergodic algorithm for active sensing \(00:14, 2016\)](#).

**Mechanics of undulatory propulsion.** Over a thousand aquatic species use undulatory fins for movement. We have characterized key principles of the generation of propulsion from these structures, along with flow structure characterization, and stability and maneuverability implications. Some of the more interesting findings have included the discovery of convergent evolution of a mechanically optimal form of fin undulation across almost two dozen species in three phyla; that inwardly counter-propagating traveling waves are often used by these swimmers to simultaneously enhance maneuverability and stability as well as provide a direction of thrust that is at right angles to the axis of the propulsor; and that flow structures emanating from these fins have unique features compared to tail-flapping type swimmers. Broader implications include one of the first times an animal propulsor has been characterized to an extent sufficient for high performance, well-controlled robotic implementation. Hyperlinks to relevant work: [J24](#), [J22](#), [J21](#), [J20](#), [J17](#), [J16](#), [J15](#), [J13](#), [J12](#), [J11](#).

**Robots and algorithms targeting bio-inspired sensing and movement.** A key means for advancing our work on sensorimotor integration has been a fleet of specialized robots for robotic experimentation and synergy with biological efforts. One lineage of these robots deploys an engineered version of active electrosense, the first time that active electrosense has been translated into a working machine, and an inspiration for several groups that now pursue engineered electrosense. Another lineage of robots take their cue from the unique propulsion system of electric fish, using undulation of an elongated fin on a rigid body for propulsion during swimming. Some of the key findings in the electrosense robotics work include development of the first algorithm to determine the shape, size, and distance of spheroids using active electrosense; development of “stereo” electrosense that detects complex impedance, and the demonstration that this leads to enhanced detection range; and application of a new ergodic approach to trajectory optimization as a formalization of active sensing for its integration into technology. The biomimetic propulsion robotics efforts have resulted in understanding an animal mode of movement to a sufficient level of detail to enable high performance, well-controlled robotic motion; and discovery of how kinematic parameters for robotic undulators relate to their mechanical force generation capability. Our current effort is focused on a 66 degree of freedom autonomous knifefish-inspired robot with a displacement of under 800 ml. This will be completed in the next six months and is expected to be a very productive platform for insights into agile control. Hyperlinks to relevant work: [J26](#), [J27](#), [J25](#), [C09](#), [J23](#), [J19](#), [J16](#), [J09](#), [C08](#), [C10](#), [C07](#), [C06](#), [C05](#), [C04](#), [C03](#), [C02](#), [J04](#). [Video on applications of electric fish robots \(00:25, 2014\)](#). [Video explaining ergodic algorithm for active sensing \(00:14, 2016\)](#).

**Evolution of movement and higher cognitive capacities.** Our earlier work mentioned above regarding the motor analog of sensing range—“motor range” or motor volume—led to the discovery that visual range was quite short in our water-borne ancestors of about 400 million years ago. Remarkably, fossils of early tetrapods from that era disclose that before we arrived on land, eyes tripled in size, most likely because we were hunting a bounty of invertebrates already on land through aerial vision, crocodile-style. This suggests that it was long-range vision, fueled

by the transparency of air over water, that led our vertebrate ancestors on to land, rather than limbs. Work on motor and sensory volumes has also led to an index of behavioral complexity as a function of how much larger sensory range is over immediate motor range (roughly, the amount of space we cover in the sensorimotor delay time at typical movement velocities). An examination of that relationship indicates that animals in water are largely trapped in a “reactive” regime in which sensory data needs to proceed through to motor output with no delay for complex decision making. Animals on land, due to the vastly larger attenuation length of light in air compared to water (photons travel 100,000 times further before scattering/absorption) are at least eligible for evolving behavioral control in what we call the “deliberative mode,” where multiple futures are contemplated and the one likely to maximize fitness is selected. Hyperlinks to relevant work: [J29](#), [short animation on why fish came up on to land](#), [J28](#), [I02](#), [B33](#), [B34](#), [B35](#), [J08](#), [J14](#), [J24](#), [I04](#). [TedXCaltech video on connection between motor & sensory volumes and consciousness](#).

**Quantification of prey capture behavior and associated sensory signals.** Through a combination of a custom infrared videography system for fish behavior, a partially automatic 3D tracking system, and a series of computational models, we calculated the full array of sensory signal input that occurs when weakly electric fish pursue their live prey. This was done for active electrosense, passive electrosense, and lateral line mechanosense. This is one of the first times the full array of sensory signals relating to behavior has been estimated for any animal. Prior to this work, all physiology in this model system was with the use of stimuli that excited the full array of sensors simultaneously. Following our work, various laboratories started testing the effect of small dipole signal sources with similar spatial and temporal frequency content as we documented occur with live prey. This has resulted in the discovery that active electrosense is processed in two pathways with very different properties: one pathway dedicated to full body stimuli, which occur during communication behaviors, and one pathway dedicated to prey-related focal stimuli, which occur during prey capture behaviors. It has also led to a better understanding of the mechanisms by which first order sensory nuclei differentially process different types of signals through descending feedback control of the filtering properties of neurons, and the use of movement for information enhancement. More recently we have begun to work on the larval zebrafish model system and quantification of prey capture in this system and associated visual signals. Our objective is to use the full suite of tools we have developed within our electric fish research (quantitative behavioral analysis, modeling, simulation, and robo-physical models) to a system where neural circuits are more easily probed with modern imaging and genetic tools. The overall objective of this portion of our work is to obtain a mechanistic understanding of how sensing, mechanics, and neural circuitry is interwoven for high agility in complex environments, and how this can be emulated in robots. Hyperlinks to relevant work: [J30](#) (in press), [J18](#), [J08](#), [J07](#), [J05](#), [J03](#), [J02](#), [J01](#), [C01](#).

## PEER REVIEWED JOURNAL ARTICLES

\*ASTERISK INDICATES CO-CORRESPONDING AUTHOR

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[J30](#) Bhattacharyya, Kiran D. and McLean, David L. and MacIver, M. A. (2017) Visual threat assessment and reticulospinal encoding of calibrated responses in larval zebrafish. *Current*

*Biology* (in press).

J29 MacIver, M.A., Schmitz, L., Muga, U, Murphey, T.D, and Curtis D. Mobley (2017). Massive increase in visual range preceded the origin of terrestrial vertebrates. *Proceedings of the National Academy of Sciences*, 114(12):E2375-E2384. doi: 10.1073/pnas.1615563114 [Link to Open Access PDF](#).

J28 Krakauer, J.W., Ghazanfar, A.A., Gomez-Marín A., MacIver, M.A., and David Poeppel (2017). Neuroscience Needs Behavior: Correcting a Reductionist Bias. *Neuron*, 93(3): 480-490. [Link to PDF](#).

J27. Fang, S., Peshkin, M. and MacIver, M. A. (2016) Human-in-the-loop active electrosense. *Bioinspiration & Biomimetics*, vol 12, issue 1, pp. 014001, 12/2016, doi: 10.1088/1748-3190/12/1/014001. [Link to PDF](#).

J26. Bai, Y., Neveln I.D., Peshkin M., and MacIver, M. A. (2016) Enhanced detection performance in electrosense through capacitive sensing. *Bioinspiration & Biomimetics*. doi: 10.1088/1748-3190/11/5/055001. [Link to PDF](#).

J25. Miller, L. M., Y. Silverman, M. A. MacIver, and T. D. Murphey (2016). Ergodic Exploration of Distributed Information. *IEEE Transactions on Robotics*, 32(1), 36-52. [Link to PDF](#). [Link to video](#) explaining the algorithm (Script and narration: MacIver).

J24. Bale, R., A. P. S. Bhalla, I. D. Neveln, M. A. MacIver\*, and N. A. Patankar (2015). Convergent evolution of mechanically optimal locomotion in aquatic invertebrates and vertebrates. *PLOS Biology* 2015, DOI: 10.1371/journal.pbio.1002123. [Link to PDF](#).

J23. Bai, Y., J. B. Snyder, M. A. Peshkin, and M. A. MacIver, Localizing and identifying underwater objects with active electrosense (2015). *The International Journal of Robotics Research*. DOI: 10.1177/0278364915569813. [Link to PDF](#).

J22. Bale, R. A., Shirgaonkar, A. A., Neveln, I. D., Bhalla, A. P. S., MacIver, M. A., Patankar, N.A. Separability of drag and thrust in undulatory animals and machines (2014). *Scientific Reports* (4), doi:10.1038/srep07329. [Link to PDF](#).

J21. Neveln, I. D., Bale, R., Bhalla, A. P. S., Curet, O. M., Patankar, N. A., MacIver, M. A. (2014) Undulating fins produce off-axis thrust and flow structures. *Journal of Experimental Biology*, 217, 201-213. [Link to PDF](#).

J20. Sefati, S., I. Neveln, E. Roth, T. Mitchell, J. B. Snyder, M. A. MacIver, E. S. Fortune, and Cowan, N. J. (2013). Mutually opposing forces during locomotion can eliminate the tradeoff between maneuverability and stability. *Proceedings of the National Academy of Sciences*, 110 (47) 18798-18803. [Link to PDF](#).

J19. Neveln, I. D., Bai, Y., Snyder, J. B., Solberg, James R., Curet, O. M., Lynch, Kevin M., & MacIver, M. A. (2013). Biomimetic and bio-inspired robotics in electric fish research. *Journal of Experimental Biology*, 216, 2501-2514. [Link to PDF](#).

J18. Patterson, B.W., Abraham, A.O., MacIver, M.A., & McLean, D. L. (2013). Visually guided gradation of prey capture movements in larval zebrafish. *Journal of Experimental Biology*, 216, 3071-3083. [Link to PDF](#).

- J17. Ruiz-Torres, R., Curet, O. M., Lauder, G. V., & MacIver, M.A. (2012). Kinematics of the ribbon fin in hovering and swimming of the electric ghost knifefish. *Journal of Experimental Biology*, 216, 823-834. [Link to PDF](#).
- J16. Curet, O.M., Patankar, N. A., Lauder, G.V., MacIver, M. A. (2011) Mechanical properties of a bio-inspired robotic knifefish with an undulatory propulsor. *Bioinspiration & Biomimetics*, Jun;6(2):026004. Epub April 7, 2011, doi:10.1088/1748-3182/6/2/026004. [Link to PDF](#).
- J15. Curet, O.M., Patankar, N. A., Lauder, G.V., MacIver, M. A. (2011) Aquatic maneuvering with counter-propagating waves: a novel locomotive strategy. *Journal of the Royal Society Interface*, July 6; 8(60):1041-50 Epub Dec 22, 2010, doi: 10.1098/rsif.2010.0493. **Cover**. [Link to PDF](#).
- J14. MacIver, M.A., Patankar, N. A., Shirgaonkar, A. A. (2010) Energy-information trade-offs between movement and sensing. *PLoS Computational Biology* 6(5): e1000769. doi: 10.1371/journal.pcbi.1000769. [Link to PDF](#).
- J13. Curet, O.M., AlAli, I. K., MacIver, M.A., Patankar, N. A. (2010) A versatile implicit iterative approach for fully resolved simulation of self-propulsion. *Computer Methods in Applied Mechanics and Engineering*, doi:10.1016/j.cma.2010.03.026. [Link to PDF](#).
- J12. Shirgaonkar, A. S., MacIver, M. A., Patankar, N. A. (2009) A new mathematical formulation and fast algorithm for fully resolved simulation of self-propulsion. *Journal of Computational Physics*, 228, 2366-2390. [Link to PDF](#).
- J11. Postlethwaite, C. M., Psemeneki, T. M., Selimkhanov\*, J., Silber, M., MacIver, M. A. (2009) Optimal movement in the prey strikes of weakly electric fish: A case study of the interplay of body plan and movement capability. *Journal of the Royal Society Interface*. Published online Oct 8, 2008; doi:10.1098/rsif.2008.0286; published in journal 2009. \*Undergraduate researcher. [Link to PDF](#).
- J10. Shirgaonkar, A. A., Curet, O.M., Patankar, N. A., MacIver, M. A. (2008) The hydrodynamics of ribbon-fin propulsion under impulsive motion. *Journal of Experimental Biology* 211: 3490-3503. [Link to PDF](#).
- J09. Solberg, J. R., Lynch, K. M., & MacIver, M. A. (2008). Active electrolocation for underwater target localization. *International Journal of Robotics Research*, 27(5), 529-548. [Link to PDF](#).
- J08. Snyder, J.B., Nelson, M.E., Burdick, J. W., MacIver, M.A. (2007) Omnidirectional sensory and movement volumes in electric fish. *PLoS Biology* 5(11): e301. [Link to PDF](#).
- J07. Nelson, M.E. and MacIver, M.A. (2006) Sensory acquisition in active sensing systems. *Journal of Comparative Physiology A* 192: 573-586. [Link to PDF](#).
- J06. 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. [Link to PDF](#).



- J05. Nelson, M.E., MacIver, M.A., Coombs, S. (2002) Modeling electrosensory and mechanosensory images during the predatory behavior of weakly electric fish. *Brain, Behavior, and Evolution* 59(4): 199-210. [Link to PDF](#).
- J04. MacIver, M.A., Nelson, M.E. (2001) Towards a biorobotic electrosensory system. *Autonomous Robots* 11, 263–266. [Link to PDF](#).
- J03. MacIver, M.A., Sharabash, N. M., Nelson, M.E. (2001) Prey-capture behavior in gymnotid electric fish: motion analysis and effects of water conductivity. *Journal of Experimental Biology*, 204(3): 543-557. [Link to PDF](#).
- J02. MacIver, M.A., Nelson, M.E. (2000) Body modeling and model-based tracking for neuroethology. *Journal of Neuroscience Methods*, 95(2):133-143. [Link to PDF](#).
- J01. Nelson, M.E., MacIver, M.A. (1999) Prey capture in the weakly electric fish *Apteronotus albifrons*: Sensory acquisition strategies and electrosensory consequences. *Journal of Experimental Biology*, 202(10):1195-1203. **Cover**. [Link to PDF](#).

## INVITED BOOK CHAPTERS, REVIEWS, ARTICLES, ETC

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- I04. MacIver, M. A. (2013) Engineering Health and Sustainability through Consciousness-Enhancing Technologies, *McCormick Magazine*, Spring 2013, Northwestern University, pp. 18-19. [Link to PDF](#).
- I03. MacIver, M. A. Fitting Science and Screen [Book Review]. *Science*, 6 May 2011: Vol. 332 no. 6030 p. 665. DOI: 10.1126/science.1205130. [Link to PDF](#).
- I02. MacIver, M.A. Neuroethology: From Morphological Computation to Planning (2009). *The Cambridge Handbook of Situated Cognition*, Robbins P. & Aydede, M. (eds). Cambridge University Press: Chapter 26, 480-504. [Link to PDF](#).
- I01. MacIver, M.A. (2001) How building physical models can reduce and guide the abstraction of nature. *Brain and Behavioral Sciences* 24(6):1066-1067. [Link to PDF](#).

## VIDEO ANIMATION

2017. Our Short-Sighted Inner Fish. Written and Produced by Kristin Pichaske in collaboration with Malcolm A. MacIver. Animation by Kaleida Studios and Cartuna. Animators: Julie Gratz, Kevin Ryan, and Kinga Nagorka. Music and Sound: Noah Pardo. [Link to video](#).

## ART SHOWS

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2011 **scale**, Malcolm A. MacIver, Marlena Novak, and Jay Allan Yim. **translife**, International Triennial of New Media Art. **National Art Museum of China**, July 27—August 17, 2011, Beijing, China. **Documentation**: [Exhibit Statement and Video at this web location](#) ([http://nrx.northwestern.edu/people/malcolm-maciver?qt-profile\\_tabs=4#qt-profile\\_tabs](http://nrx.northwestern.edu/people/malcolm-maciver?qt-profile_tabs=4#qt-profile_tabs)) Estimated participation: 10,000.

2010 **scale**, Malcolm A. MacIver, Marlena Novak, and Jay Allan Yim. World premiere at the **STRP Festival of Art and Technology in Eindhoven**, The Netherlands, Nov 18-28 2010. The [STRP](#) Festival is one of the largest e-culture events in Europe which melds music, art & technology together. 30,000 people visited the festival during the premiere.

2003 **Body Electric**, Malcolm A. MacIver and Simon Penny. **Williamson Art Gallery** in the Art Center College of Design in Pasadena CA, April 15-June 29 2003. Part of the NEURO exhibition developed by the Caltech Center for Neuromorphic Systems Engineering and the Williamson Art Gallery. **Documentation:** [Exhibit Statement and Video at this web location](http://nrx.northwestern.edu/people/malcolm-maciver/qt-profile_tabs=4#qt-profile_tabs) ([http://nrx.northwestern.edu/people/malcolm-maciver/qt-profile\\_tabs=4#qt-profile\\_tabs](http://nrx.northwestern.edu/people/malcolm-maciver/qt-profile_tabs=4#qt-profile_tabs))

## SELECT MOVIE AND TV SERIES SCIENCE ADVISING

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2015 Advisor, *Terminator Genisys*

2015 Advisor, *The Avengers: Age of Ultron*

2013 Advisor, *Superman, Man of Steel*

2010 *Tron Legacy*

2009-2010 Robotics & science script consultant for SyFy Channel's prequel to Battlestar Galactica, *Caprica*, Seasons 1 & 2.

## PEER REVIEWED CONFERENCE PROCEEDINGS

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C12. Ugurcan, M., M. A. MacIver, and M. Peshkin, Information-theoretic approach to sensor selection, 2017. The 8th International Symposium on Adaptive Motion of Animals and Machines, Sapporo Japan.

C11. Mamakoukas, G., M. A. MacIver, and T. D. Murphey, Feedback Synthesis for Controllable Underactuated Systems using Sequential Second Order Actions, Robotics: Science and Systems, 2017. [Link to PDF](#).

C10. Mamakoukas, G., M. A. MacIver, and Todd. D. Murphey. Controlling Underactuated Underwater Vehicles with Added Mass and Velocity Drift Using Sequential Action Control. American Control Conference, Boston MA, 2016. [Link to PDF](#).

C09. Neveln, I. D., L. M. Miller, M. A. MacIver, and T. D. Murphey, Improving Object Tracking through Distributed Exploration of an Information Map, IEEE Int. Conf. on Intelligent Robots and Systems (IROS), 2014. Pages: 3441 - 3447, doi: 10.1109/IROS.2014.6943042. [Link to PDF](#).

C08. Silverman, Y., L. M. Miller, M. A. MacIver, and Murphey, T.D. (2013) Optimal Planning for Information Acquisition. Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference, p5974-5980, Tokyo Japan. doi: 10.1109/IROS.2013.6697223.



[Link to PDF.](#)

C07. Shahin Sefati, Izaak Neveln, Malcolm A. MacIver, Eric Fortune, Noah J. Cowan (2012). Counter-Propagating Waves Enhance Maneuverability and Stability: A Bio-Inspired Strategy for Robotic Ribbon-Fin Propulsion. *Biomedical Robotics and Biomechatronics (BioRob)*, 2012 4th IEEE RAS & EMBS International Conference on, pp. 1620-1625. DOI: 10.1109/BioRob.2012.6290909. [Link to PDF.](#)

C06. Yonatan Silverman, James Snyder, Yang Bai, and Malcolm A. MacIver (2012) Location and Orientation Estimation with an Electrosense Robot. *Intelligent Robots and Systems (IROS)*, 2012 IEEE/RSJ International Conference on, pp.4218-422e, 7-12 Oct. 2012. doi: 10.1109/IROS.2012.638617. [Link to PDF.](#)

C05. Bai, Y., Snyder, J. B., Silverman, Y., Peshkin, M. and MacIver, M.A. (2012). Sensing Capacitance of Underwater Objects in Bio-inspired Electrosense. *Intelligent Robots and Systems (IROS)*, 2012 IEEE/RSJ International Conference on, pp.1467-1472, 7-12 Oct. 2012. doi: 10.1109/IROS.2012.638617. [Link to PDF.](#)

C04. Snyder, J., Silverman, Y., Bai, Y. MacIver, M.A., (2012). Underwater object tracking using electrical impedance tomography. *Intelligent Robots and Systems (IROS)*, 2012 IEEE/RSJ International Conference on, vol., no., pp.520-525, 7-12 Oct. 2012 doi: 10.1109/IROS.2012.6386251. [Link to PDF.](#)

C03. Epstein, M., Colgate, J.E, MacIver, M.A. (2006) Generating Thrust with a Biologically-Inspired Robotic Ribbon Fin Source. 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) Beijing, China. pp: 2412 - 2417, DOI: 10.1109/IROS.2006.281681. [Link to PDF.](#)

C02. 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. [Link to PDF.](#)

C01. MacIver, M.A., Lin, J.L., Nelson, M.E. (1997) Estimation of signal characteristics during electrolocation from video analysis of prey capture behavior in weakly electric fish. *Computational Neuroscience: Trends in Research, 1997*. Plenum Press. pp. 729-734. [Link to PDF.](#)

## INVITED TALKS AT PROFESSIONAL SYMPOSIA

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| 2017 | Understanding animals through sensory evolution and robotics. German Zoological Society 110th Annual Meeting (keynote). Bielfeld, Germany.           |
| 2016 | Mechanically optimal movement in fish and its coupling to information harvesting. Fifth annual winter workshop in the neuromechanics and dynamics of |

- locomotion, Tulane University, New Orleans LA.
- 2015 Electric Fish Robotics. 7<sup>th</sup> International Symposium on Adaptive Motion of Animals and Machines. MIT, Cambridge MA.
- 2014 Vision versus electrosense. 26<sup>th</sup> Annual Karger Workshop in Evolutionary Neuroscience. November 2014, Washington DC.
- 2014 Electric fish robotics. AAAS National Meeting, Symposium on “Intelligent Autonomous Robots: Biologically Inspired Engineering”, Chicago IL.
- 2013 Vision versus electrosense: Mechanics and sensing in prey capture behavior of larval zebrafish compared to electric knifefish. Janelia Farms Conference, “Dynamics of Prey Capture and Escape” March 2013, Ashburn, VA.
- 2013 Can We Expand Our Consciousness With Neuroprosthetics? TEDx Caltech, January 2013. Pasadena CA.
- 2013 Vision versus electrosense: Mechanics and sensing in prey capture behavior in larval zebrafish compared to electric knifefish. Symposium keynote for “When Predators Attack,” Society of Integrative and Comparative Biology, January 2013, San Francisco, CA.
- 2012 How Knifefish Swim: Spanning the Gap Between Eel-like and Trout-Like Swimming. Weakly electric fish meeting, International Congress of Neuroethology August 2012, College Park MA.
- 2012 Sensory and Motor Spaces and the Emergence of Multiple Futures. Computational Neuroscience Annual Meeting, July 2012, Atlanta GA. (keynote).
- 2012 Sensory and Motor Spaces and the Emergence of Multiple Futures. Summer School in Cognitive Sciences, “The Evolution and Function of Consciousness,” June 30-July 9, Montreal Canada.
- 2012 “From electric fish to robot fish and back” PINC Conference, Amsterdam,
- 2011 “Energy, Information, and the Emergence of Choice” FQXi Conference, Copenhagen.
- 2011 “Energy-Information Trade-Offs between Movement and Sensing,” Gordon Conference on Neuroethology.
- 2011 “Energy-Information Trade-Offs between Movement and Sensing.” International workshop on bio-inspired robots, Nantes France (keynote).
- 2011 “Energy-Information Trade-Offs between Movement and Sensing.” German Society for Neuroscience, Gottingen.
- 2010 “Infomechanics and the bone-brain continuum.” Swiss Federal Institute of Technology, Life Science Symposium on Engineering Life, Lausanne, Switzerland.
- 2009 “The development of a bio-inspired magneto-electrosensory navigation module.”

- Office of Naval Research Symposium on Bio-inspired Systems, Washington DC
- 2009 “Biomechanical constraints on sensory acquisition in weakly electric fish”  
Society for Integrative and Comparative Biology, Symposium on Sensory Biomechanics, Boston, MA
2008. “Acquiring information under mechanical constraints” Fourth International Symposium on Adaptive Motion of Animals and Machines, Case Western Reserve University, Cleveland, OH
- 2007 “Sensory and movement volumes in animals: Implications for control”  
Symposium on top-down influences in active sensing. International Congress of Neuroethology, Vancouver BC Canada
- 2007 “Infomechanical specializations for maximizing prey capture in the knifefish”  
Satellite meeting on electrosensory organisms, International Congress of Neuroethology, Vancouver BC Canada
- 2007 “Robotic electrolocation: Active underwater target localization with electric fields.” Solberg, J.S., Lynch, K.M., and MacIver, M.A. International Conference for Robotics and Automation, Symposium on Bio-inspired Perception, Rome, Italy. Presenter: Solberg.
- 2006 “From morphological computation to planning: insights from neuroethology,”  
Tenth International Conference on the Simulation and Synthesis of Living Systems (ALife X), Workshop on Morphologies, Motion and Cognition, Bloomington, IN, USA
- 2006 “Generating Thrust with a Biologically-Inspired Robotic Ribbon Fin.” Epstein, M., Colgate, J. E., MacIver, M.A. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Beijing, China. Presenter: MacIver.
- 2005 “Explorations in Computational Morphology,” The Canadian Electric Fish Meeting, Merrickville, ON, Canada
- 2005 “A Biologically Inspired Robotic Ribbon Fin.” Epstein, M., Colgate, J. E., MacIver, M. A. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Edmonton, AB, Canada. Presenter: MacIver.
- 2004 “Matching of sensing and motor volumes in active sensory systems.” MacIver, M. A., Nelson, M. E., Burdick, J. W. Society for Neuroscience Satellite Symposium on Advances in Computational Motor Control, San Diego, CA, USA. Presenter: MacIver
- 2004 “Matching of sensing and motor volumes and optimality of movements in active sensory systems,” Center for Neuromorphic Systems Engineering 10<sup>th</sup> Anniversary Celebration.
- 2003 “Neuromechanical design and active sensory systems,” 13<sup>th</sup> International Symposium on Unmanned Untethered Submersible Technology, Durham, NH,

## USA

- 2003 “Getting around on a small charge: mechanics, sensing, and biorobotics with the weakly electric fish,” Second International Symposium on Aqua Bio-Mechanisms, Honolulu, HI, USA
- 2002 “Sensing, mechanics, and control: a framework for the integrated understanding of a natural behavior,” The Hebrew University and Caltech 2<sup>nd</sup> Joint Symposium on Frontiers in Computational Neuroscience, Pacific Grove, CA, USA
- 2000 “A robotic implementation of electrosensory signal acquisition in electric fish,” NASA Workshop on Biomimetic Robotics, Pasadena, CA, USA

## OTHER INVITED ACADEMIC TALKS

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1. Washington and Lee University, Physics-Engineering Seminar Series 2015
  2. University of Chicago, Chicago IL, Computational Neuroscience Seminar Series 2013
  3. University of Wisconsin, Milwaukee, Dept. of Neurobiology 2013
  4. Cornell University, Distinguished Speaker Series, BBS Seminar 2013
  5. Grand Rounds, Northwestern Department of Psychiatry 2013
  6. University of Washington, Seattle, Dept. of Computer Science & EE 2012
  7. iRobot, Durham NC 2010
  8. International Neuroethology Congress, Coupled Robot-Animal Systems 2010
  9. Northwestern University Institute of Neuroscience Retreat, St. Charles IL 2009
  10. Slivka Residence Hall Fireside Science Talk, Evanston IL 2009
  11. Dept. of Engineering Sci., U. of Illinois Urbana-Champaign 2009
  12. Division of Eng., & Dept. of Ecology and Evolutionary Biology, Brown University 2009
  13. Dept. of Biomedical Engineering, University of California Irvine 2008
  14. Program in Neuroscience and Cognitive Science, U. of Maryland, College Park, MD 2007
  15. Dept. of Mechanical Engineering, Johns Hopkins, Baltimore MD 2007
  16. Dept. of Philosophy, Univ. of Chicago, IL, USA 2006
  17. Dept. of Physiology, Northwestern U. Feinberg School of Medicine, Chicago, IL 2006
  18. IGERT Seminar Series, Machines & Organisms, Cornell University, Ithaca, NY 2006
  19. Neuroscience Program, Michigan State University, East Lansing, MI 2005
  20. Dept. of Electrical and Computer Engineering, Univ. of Illinois Chicago, IL 2005
  21. Neuroscience Program, Univ. of Illinois Urbana-Champaign, IL 2005
  22. Dept. of Biology, McGill University, Montreal, QC 2005
  23. Dept. of Physical Therapy & Human Movement Sci., Northwestern Univ. 2005
  24. Dept. of Aeronautics and Astronautics, Univ. of Washington, Seattle, WA 2005
  25. Committee on Computational Neuroscience, Univ. of Chicago, IL 2005

26. Evolutionary Discussion Group, Northwester Univ., Evanston, IL	2004
27. Sensory Motor Performance Program, Rehabilitation Institute of Chicago, IL	2003
28. IGERT Program on Dynamics of Complex systems, Evanston, IL	2003
29. Northwestern University Institute of Neuroscience, St. Charles, IL,	2003
30. Sloan Theoretical Neurobiology Seminar Series, Caltech, Pasadena CA	2002
31. Caltech Bioengineering Seminar Series, Caltech, Pasadena CA	2001
32. Beckman Institute Visualization Seminar Series, Urbana, IL	1998

## CONTRIBUTED ACADEMIC TALKS AND SELECTED POSTERS

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- 1) 2017 Adaptive Motion in Animals and Machines, Sapporo, Japan (poster)
- 2) 2016 J. B. Johnston Club for Evolutionary Neuroscience, San Diego, CA (talk)
- 3) 2016 Society for Vertebrate Paleontology, Salt Lake City, Utah (talk)
- 4) 2015 Adaptive Motion of Animals and Machines, MIT Cambridge MA (poster)
- 5) 2015 Society for Integrative and Comparative Biology, West Palm Beach FL (talk+poster),
- 6) 2013 Janelia Farms, Dynamics of Prey Capture and Escape (1 talk, 1 poster)
- 7) 2013 Society for Integrative and Comparative Biology, San Francisco (2 talks).
- 8) 2012 International Congress of Neuroethology, College Park, Maryland (2 posters).
- 9) 2012 International Conference on Intelligent Robots and Systems, Portugal (3 talks).
- 10) 2012 Fourth IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics, Rome Italy (talk)
- 11) 2012 First International Workshop on Robotic Electrosense (3 posters, 3 talks)
- 12) 2011 American Physical Society, 64<sup>th</sup> Annual Meeting (poster)
- 13) 2009 American Physical Society, 62<sup>nd</sup> Annual Meeting (talk, presenter: Curet; talk, presenter Shirgaonkar; talk, presenter: Patankar), Minneapolis, MN
- 14) 2009 Society for Neuroscience (poster), Chicago, IL
- 15) 2009 Society for Integrative and Comparative Biology (talk), Boston, MA
- 16) 2008 American Physical Society, 61st Annual Meeting (talk, presenter: MacIver) San Antonio, TX
- 17) 2008 American Physical Society, 61st Annual Meeting (talk, presenter: Curet) San Antonio, TX
- 18) 2008 American Physical Society, 61st Annual Meeting (talk, presenter: Shirgaonkar) San Antonio, TX
- 19) 2008 American Physical Society, 61st Annual Meeting (video submission to Gallery of Fluid Motion, San Antonio, TX
- 20) 2007 American Physical Society, 60th Annual Meeting (talk, presenter: MacIver), Salt Lake City, UT
- 21) 2007 American Physical Society, 60th Annual Meeting (talk, presenter: Shirgaonkar), Salt Lake City, UT
- 22) 2007 American Physical Society, 60th Annual Meeting (talk, presenter: Curet), Salt Lake City, UT

- 23) 2007 American Physical Society, 60th Annual Meeting (poster, presenter: Curet), Salt Lake City, UT
- 24) 2007 International Congress of Neuroethology, Vancouver BC (talk)
- 25) 2007 International Congress of Neuroethology, Vancouver BC (poster)
- 26) 2007 International Congress of Neuroethology, Vancouver BC (poster)
- 27) 2007 International Congress of Neuroethology, Vancouver BC (poster)
- 28) 2007 IEEE International Conference on Robotics and Automation, Rome, Italy (talk)
- 29) 2006 Biomedical Engineering Society, Chicago, IL
- 30) 2006 Society for Neuroscience, Atlanta, GA (poster)
- 31) 2006 American Physical Society, 59th Annual Meeting, with Neelesh Patankar and Oscar Curet, Tampa, FL (talk, presenter: Shirgaonkar)
- 32) 2006 American Physical Society, 59th Annual Meeting, with Oscar Curet and Neelesh Patankar, Tampa, FL (talk, presenter: MacIver)
- 33) 2005 Developmental Basis of Evolutionary Change, Chicago, IL (poster)
- 34) 2005 Developmental Basis of Evolutionary Change, Chicago, IL (poster)
- 35) 2005 Joint Dept of Neurology and Biomedical Engineering Poster Session (with T. Kuiken & A. Schultz), Chicago, IL (poster)
- 36) 2005 Southern California Joint Symposium on Computational Neuroscience (with J. Burdick), California Institute of Technology, Pasadena CA (talk)
- 37) 2005 Neural Engineering Workshop (with J. Snyder), Chicago IL
- 38) 2004 International Soc. Neuroethology, Nyborg, Denmark (with J. Burdick & M. Nelson) (poster)
- 39) 2002 Gordon Research on Sensory Coding and the Natural Environment (with M. Nelson), South Hadley, MA (poster)
- 40) 2001 International Soc. Neuroethology, Bonn, Germany (poster with M. Nelson)
- 41) 2000 Society for Neuroscience 30th Meeting, New Orleans LA (poster with M. Nelson)
- 42) 1999 Computation and Neural Systems Meeting (CNS), Pittsburgh, PA (poster with M. Nelson)
- 43) 1998 International Soc. Neuroethology, San Diego, CA (poster with M. Nelson)
- 44) 1997 Society for Neuroscience 27th Meeting, New Orleans, LA (poster with M. Nelson)
- 45) 1996 Computation and Neural Systems Meeting (CNS), Boston, MA (poster with M. Nelson)
- 46) 1995 Society for Neuroscience 25th Meeting, San Diego, CA (poster with M. Nelson)

## PUBLIC ENGAGEMENT (LINKS ACTIVE IN ELECTRONIC PDF)

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### *Public Lectures/Interviews*

2016 reddit “Ask Me Anything” [PLOS Science Wednesday](#), on our PLOS paper on the convergent evolution of mechanically optimal swimming.



- 2015 Northwestern University, Lawrence B. Dumas Domain Dinner on New Technologies That Will Be Transformative. Talk title: *Engineering Empathy*
- 2015 Chicago Museum of Science and Industry, public talk on Electric Fish Robotics in association with their new exhibition on robotics, *Robot Revolution*.
- 2014 Chicago Council on Science and Technology talk and panel discussion on *The Future of Work*. [Video at this location](https://www.youtube.com/watch?v=PcQ68vTPXb4) (https://www.youtube.com/watch?v=PcQ68vTPXb4)
- 2014 PBS TV affiliate WTTW panel discussion on the *Future of Work*, Chicago Tonight. [Video at this location](http://chicagotonight.wttw.com/node/17033) (http://chicagotonight.wttw.com/node/17033)
- 2014 *Big Data in Neuroscience*, talk for the Shirley Ryan Learning for Life Series.
- 2014 *Cheetahs, Fish, Fingers & Bacteria: The coming menagerie of mechanical cohabitants*. Panel discussion for the Adler Planetarium public event “Hops’n Bots”, with Sangbae Kim (MIT), Antonio Bicci (University of Pisa), and Bradley Nelson (ETH Switzerland).
- 2014 *The Future of Artificial Intelligence*, interview with the creators of the CBS TV Series *Person of Interest* for Season 3 DVD Extra. [Video at this location](https://www.dropbox.com/s/2hlp6805vgbwee0/PERSON_OF_INTEREST_S3_DISC_6.m4v?dl=0), at two minutes forty seconds (https://www.dropbox.com/s/2hlp6805vgbwee0/PERSON\_OF\_INTEREST\_S3\_DISC\_6.m4v?dl=0)
- 2014 BBC World Service (Interview) on developing robotic fish. [Audio at this location](http://nrx.northwestern.edu/sites/default/files/files/BBC_WorldService_Newsday_20140217_0700GMT.mp3) (http://nrx.northwestern.edu/sites/default/files/files/BBC\_WorldService\_Newsday\_20140217\_0700GMT.mp3)
- 2014 BBC Radio 5 (Interview) on the development of a robot fish. [Audio at this location](http://nrx.northwestern.edu/sites/default/files/files/BBC_RADIO5_UpAllNight_20140217_0400GMT.mp3) (http://nrx.northwestern.edu/sites/default/files/files/BBC\_RADIO5\_UpAllNight\_20140217\_0400GMT.mp3)
- 2014 BBC *Amazon electric fish inspire underwater robotics*. [Story and video at this location](http://www.bbc.com/news/science-environment-26025563) (http://www.bbc.com/news/science-environment-26025563).
- 2013 Interview by Jennifer Ouellette for the show Virtually Speaking Science on my biography, science advising to movie makers, and a variety of science topics. [Audio at this location](http://www.blogtalkradio.com/virtually-speaking-science/2013/09/12/jennifer-ouellette-malcolm-maciver-neuroprosthetics-1) (http://www.blogtalkradio.com/virtually-speaking-science/2013/09/12/jennifer-ouellette-malcolm-maciver-neuroprosthetics-1)
- 2013 *Can We Expand Our Consciousness With Neuroprosthetics?* TEDx Caltech, January 2013. Pasadena CA. [Video at this location](https://www.youtube.com/watch?v=gj2zx1kEjKM&list=PLsRNoUx8w3rP8morYo0ZmBAwrEpJVr51X) (https://www.youtube.com/watch?v=gj2zx1kEjKM&list=PLsRNoUx8w3rP8morYo0ZmBAwrEpJVr51X)

- 2013 Discovery Science Channel, *Alien Encounters* Season 2, Episodes 1-2, Commentator, March 2013.
- 2012 *From electric fish to robot fish and back* PINC Conference, Amsterdam
- 2010-2012. Blogger on robotics, artificial intelligence, and neuroscience for Science Not Fiction, Discover Magazine. Links to posts above.
- 2011 “Death and the Powers” Public panel on the new robot opera by Tod Machover, with Tod Machover, March 2, 2011, Dean’s Seminar Series, McCormick School of Engineering, Northwestern University. Article and video: [http://www.mccormick.northwestern.edu/news/articles/archive/2009-2012/article\\_852.html](http://www.mccormick.northwestern.edu/news/articles/archive/2009-2012/article_852.html)
- 2011 *Science of Cyborgs* March 1, 2011, Directors Guild of America, Los Angeles CA. Talk on movie portrayals of robotics and androids, transhumanism, and the evolutionary basis of consciousness. Article and video of presentation: <http://www.scienceandentertainmentexchange.org/blog/science-cyborgs>
- 2011 Interview on NPR Chicago affiliate WBEZ *Clever Apes* radio program on the origin and history of consciousness. [Story and audio here \(http://www.wbez.org/blog/clever-apes/2011-05-24/clever-apes-13-origin-stories-86999\)](http://www.wbez.org/blog/clever-apes/2011-05-24/clever-apes-13-origin-stories-86999)
- 2010 Interview on the National Academy of Engineering Innovation Podcast and Radio Series *Body Intelligence--Does all cleverness and intelligence come from our brains? That may seem logical, but may not be the case.* [Audio here \(http://www.nae.edu/Projects/20730/wtop/27253.aspx\)](http://www.nae.edu/Projects/20730/wtop/27253.aspx)
- 2010 Science Café “The Evolution of Consciousness” March 17, 2010, Firehouse Grill Evanston IL. [Media coverage of event \(https://helix.northwestern.edu/article/thinking-about-next-move-350-million-years-consciousness\)](https://helix.northwestern.edu/article/thinking-about-next-move-350-million-years-consciousness).
- 2010 Interview on NPR Chicago affiliate WBEZ *Clever Apes* radio program on the electric fish art installation “scale”. [Story and audio here \(http://www.wbez.org/blog/clever-apes/clever-apes-light-sabers-and-fish-choir\)](http://www.wbez.org/blog/clever-apes/clever-apes-light-sabers-and-fish-choir)
- 2009-2010 Blogger for the Science in Society Blog, Feinberg School of Medicine. <http://blog.scienceinsociety.northwestern.edu/author/mmaciver/>
- 2009 Science consultant for TRON Legacy, as part of the National Academy of Science’s “Science Entertainment Exchange Program” to bring better science to Hollywood.
- 2009 Lecturer for the Illinois Science Council’s Science Café “Body Electric: Lightning, defibs, and Tasers” at Lucky Strike (AMC Theater Building), 322 E Illinois St., Chicago

IL.

- 2003 NSF High School Teacher Program, worked with a Los Angeles inner city school district teacher to bring biofluids research to high schools
- 2003 NSF & Caltech sponsored art show, Williamson Gallery in Pasadena, interactive art installation on active sensing with Simon Penny. More details at <http://www.neuromech.northwestern.edu/uropatagium/#ArtSci>

### *Select Blog Posts*

B37. Information Wants to Be Free. What About Killer Information? [Discover Magazine Online. Dec 27, 2011.](#)

B36. The Geek Rapture and Other Musings of William Gibson [Discover Magazine Online. Oct 17, 2011.](#)

B35. Why Did Consciousness Evolve, and How Can We Modify It, Pt. III: Memory, Communication, and Perception [Discover Magazine Online. Aug 8, 2011.](#)

B34. Why Did Consciousness Evolve, and How Can We Modify It, Pt. II: The Supremacy of Vision [Discover Magazine Online. Mar 23, 2011.](#)

B33. Why Did Consciousness Evolve, and How Can We Modify It? [Discover Magazine Online. Mar 14, 2011.](#)

B32. Transhumanism: A Secular Sandbox for Exploring the Afterlife? [Discover Magazine Online. Feb 28, 2011.](#)

B30. A Robots That Evolve Like Animals Are Tough and Smart—Like Animals [Discover Magazine Online. Feb 14, 2011.](#)

B29. A Does AI Need Guts to Get to the Singularity? [Discover Magazine Online. Feb 2, 2011.](#)

B28. A New Robot for the Bestiary: How to Build a Robotic Ghost Fish [Discover Magazine Online. Jan 26, 2011.](#)

B27. The Real-Life District 9—Class and Sci-Fi in South Africa [Discover Magazine Online. Jan 12, 2011.](#)

B26. Would Death Be Easier If You Know You've Been Cloned? [Discover Magazine Online. Dec 27, 2010.](#)

B25. Killing The Dr. Evils of Iran: Is it Open Season On Scientists? [Discover Magazine Online. Nov 30, 2010.](#)

B24. How to Conduct the World's First Electric Fish Orchestra [Discover Magazine Online. Nov 23, 2010.](#)

- B23. Mutants, Androids, Cyborgs and Pop Culture Films [Discover Magazine Online. Nov 2, 2010.](#)
- B22. Electric Fish "Plug in" and Turn Their Zapping Into Music [Discover Magazine Online. Oct 23, 2010.](#)
- B21. Caprica Puzzle: If a Digital You Lives Forever, Are You Immortal? [Discover Magazine Online. Oct 5, 2010.](#)
- B20. I Have Seen the Furniture, and It Is Robotic. [Discover Magazine Online. Sept 28, 2010.](#)
- B19. A Robot Science Fiction and the Modding of Our Future. [Discover Magazine Online. Sept 22, 2010.](#)
- B18. A Robot That Tries To Rock You Asleep, [Discover Magazine Online. Sept 14, 2010.](#)
- B17. Is AI More Common Than Biological Intelligence Across the Universe?, [Discover Magazine Online. Aug 31, 2010.](#)
- B16. The New AI: Turn Robots Into Infant Scientists, [Discover Magazine Online. Aug 25, 2010.](#)
- B15. Amplifying Our Brain Power Through Better Interactive Holographics, [Discover Magazine Online. Aug 10, 2010.](#)
- B14. Inception and the Neuroscience of Sleep, [Discover Magazine Online. Aug 10, 2010.](#)
- B13. Why Keep Your Body? Help Yourself to Big Muscles, Cyborg Limbs, and a Big Booty. [Discover Magazine Online. Jul 27, 2010.](#)
- B12. When Sci-Fi Plays Play With Your Identity, [Discover Magazine Online. Jul 19, 2010.](#)
- B11. Hairshirted Eye for the Irritable Guy: New Study Shows How the Feel of Things Affects Thought, [Discover Magazine Online. Jul 7, 2010.](#)
- B10. IBM Computer Fails the Turing Test But Just Might Pass the Jeopardy Test. Science Not Fiction Blog, [Discover Magazine Online. June 28, 2010.](#)
- B09. The Animal Superpower That Robots Would Love to Have: Great Efficiency. Science Not Fiction Blog, [Discover Magazine Online. June 18, 2010.](#)
- B08. Guest Post: Malcolm MacIver on War with the Cylons. [Sean Carroll's Blog, April 26 2010.](#)
- B07. Are we 'wired for war' with cylons? [Science and Society Helix Blog, Feb 11, 2009.](#)
- B06. "A scary thing happened" --- How to make child's play of disasters. [Science and Society Helix Blog, June 5, 2009.](#)
- B05. Homeopathy and the limits of science. [Science and Society Helix Blog, April 5, 2009.](#)
- B04. Is it time to shut down the national center for complementary and alternative medicine (NCCAM)? [Science and Society Helix Blog, March 23, 2009.](#)
- B03. The Science Entertainment Exchange, Pt II. [Science and Society Helix Blog, Feb 25,](#)

[2009.](#)

B02. The Science Entertainment Exchange, Pt II. [Science and Society Helix Blog, Feb 25, 2009.](#)

B01. The Science Entertainment Exchange, Pt II. [Science and Society Helix Blog, Feb 25, 2009.](#)

## ACTIVE FUNDING

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### **Development of a climate change prediction market for behavioral change**

Principal Investigator: Malcolm MacIver

Co-Investigator: Moran Cerf

Agency: Northwestern Institute on Complex Systems

Period 03/01/2015-present

### **Reticulospinal Execution of Innate Decision-Making**

Principal Investigator: David McLean

Co-Investigators: Malcolm MacIver, Neelesh Patankar

Agency: National Science Foundation, IOS-ORG 1456830

Period: 5/01/2015-4/30/2019

### **A Bio-Inspired underwater robot for station keeping with omnidirectional disturbances**

Principal Investigator: Malcolm MacIver

Co-Investigators: Michael Peshkin, Todd Murphey.

Agency: Office of Naval Research, N00014-14-1-0594.

Period: 5/1/14-9/30/17

### **NRI: Electrosense imaging for underwater telepresence and manipulation**

Principal Investigator: Michael Peshkin

Co-Investigators: Malcolm MacIver, Joshua Smith, Konrad Kording, Alex Mahklin.

Agency: National Science Foundation, NSF IIS-1427419

Period: 9/1/2014-8/30/2017

## COMPLETED FUNDING

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### **Cyber-Enabled Discovery in Neuromechanical Systems**

Principal Investigator: Malcolm A. MacIver

Co-Investigators: Noah Cowan and Eric Fortune (Johns Hopkins), George Lauder (Harvard)

Agency: National Science Foundation, NSF CMMI-0941674

Period: 9/1/2009-8/31/2015

**CAREER: Infomechanics - The interdependence of animal information acquisition and mechanics**

Principal Investigator: Malcolm MacIver  
Agency: National Science Foundation, IOB-0846032  
Period: 8/15/2009-6/30/2015

**IGERT: Integrative Training in Motor Control and Movement**

Principal Investigator: Melina Hale (University of Chicago)  
Co-Investigator: Malcolm A. MacIver, and three others at University of Chicago  
Agency: National Science Foundation  
Period: 8/1/2009-7/31/2014

**The development of a bio-inspired magnetolectrosensory navigation system**

Principal Investigator: Malcolm MacIver  
Co-Investigators: Kinea Design LLC, Michael Peshkin, Kevin Lynch  
Agency: Office of Naval Research, STTR mechanism, Phase II, N00014-10-C0420  
Period: 1/5/2010-12/1/2012

**Fully resolved simulation of self-propelling fish**

Principal Investigator: Neelesh A. Patankar  
Co-Investigator: Malcolm A. MacIver  
Agency: National Science Foundation, CBET-0828749  
Period: 9/1/2008-8/31/2012

**scale**

Principal Investigator: Malcolm MacIver  
Co-Investigators: Jay Allan Yim, School of Music at Northwestern University, and Marlina Novak, Weinberg College of Arts and Sciences at Northwestern University.  
Agency: Northwestern Center for Interdisciplinary Research in the Arts  
Period: 7/15/2009-7/14/2010

**The development of a bio-inspired magnetolectrosensory navigation system**

Principal Investigator: Malcolm MacIver  
Co-Investigators: Kinea Design LLC, Michael Peshkin, Kevin Lynch  
Agency: Office of Naval Research, STTR mechanism  
Period: 6/29/2009-1/25/2010

**Transforming sensory signals into muscle activations in a behavior with dynamic constraints**

Principal Investigator: Malcolm A. MacIver  
Co-Investigator: Kevin Lynch (ME)  
Agency: National Science Foundation IOB-0517683  
Period: 8/1/2005-10/2008



## TRAINEE FELLOWSHIPS

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2013-2016 Kiran D. Bhattacharyya, NSF Graduate Fellowship

2013-2015 Matt Green, NSF Postdoctoral Fellowship

2006-2010 Oscar Curet, Diversifying Higher Education Faculty in Illinois Graduate Fellowship

## MENTORING

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### Postdoctoral Associates

Matthew Hobson Green, 2012--

Srinivas Ramakrishnan (Co-supervised with N. Patankar), 2009. Current position: Senior Software Developer at ANSYS, Inc.

Anup Shirgaonkar (Co-supervised with N. Patankar), Current position: Quantitative Strategist in Investment Management, Quantitative Machines.

Claire Postlethwaite (Co-supervised with M. Silber), 2006-Jun 2008: Assistant Professor, University of Auckland, New Zealand.

### Graduate Students

#### Current Ph.D. students

Ugurcan Mugan, Biomedical Engineering

Kiran D. Bhattacharyya, Biomedical Engineering

Chen Chen, Biomedical Engineering

#### Current M.S. in Robotics students

Luke Shi

#### Completed Ph.D. students

Yang Bai, Mechanical Engineering (with Michael Peshkin). Current position: Machine learning researcher at Google.

Izaak Neveln, Biomedical Engineering. Current position: Postdoctoral scholar in Simon Sponberg's laboratory, Georgia Tech, School of Physics & School of Applied Physiology.

Brad Patterson, Northwestern University Interdepartmental Neuroscience Program. (with David McLean). Current position: In training to be a US Army intelligence officer.

James Snyder, Biomedical Engineering. Current position: Engineering consultant and technology developer for embedded systems.

Rahul Bale, Mechanical Engineering (with Neelesh Patankar). Current position: Postdoc,  
RIKEN, Japan.

Oscar Curet (with N. Patankar), Mechanical Engineering (2003-2009). Current position:  
Assistant Professor, Department of Ocean and Mechanical Engineering, Florida  
Atlantic University, Boca Raton.

Michael Epstein, Mechanical Engineering (with E. Colgate) (2003-2007). Current position:  
Consulting.

James Solberg, Mechanical Engineering (with K. Lynch) (2003-2007). Current position: Senior  
Controls Engineer, HDT Expeditionary Systems Inc., Evanston IL.

Completed Masters students

Abhishek N. Patil (Robotics, 2016)

Sandra Fang, Mechanical Engineering (2014-2016), Current position: JPL.

Ritwik Ummalneni (Robotics, 2016)

Sun Yue (Robotics, 2015)

Yoni Silverman, Mechanical Engineering (2010-2013). Current position: Research engineer at a  
Chicago area nuclear power controls company.

Aimee Schultz, Mechanical Engineering (2004-2007). Current position: Self-employed academic  
science paper writer.

Thesis Committees

Peter Winter, Chemical and Biological Engineering, PhD

Thomas Harmon, Northwestern Interdepartmental Neuroscience Program, PhD

David Meyer, Mechanical Engineering, PhD

James Aaron Ellis, Biomedical Engineering, MS

Mao Mao, Mechanical Engineering, PhD

Elliot Johnson, Mechanical Engineering, PhD

Matthew Geary, Biomedical Engineering PhD

Brian London, Northwestern Interdepartmental Neuroscience Program PhD

Dhwanil Damania, Biomedical Engineering MS

Vladimir Turzhitsky, Biomedical Engineering PhD

Hariharan Subramanian, Biomedical Engineering PhD

Lexyne McNealy, Department of Physical Medicine and Rehabilitation MS

Michael Siegel, Biomedical Engineering MS

Albert Chen, Biomedical Engineering, PhD

Northwestern University Interdepartmental Neuroscience Program Student 3 Month Rotations:  
Sam Minkowicz (2017), Chris Mullens (2010), Ricardo Ruiz-Torres (2009), Lydia Wood (2005),  
Brian London (2004)

### Undergraduate Students

2016 Alfred Astor, Mechanical Engineering & Neurobiology  
2015 Jonathan Denose (Electrical Engineering, URM), Michael Smith (Computer Science,  
URM), Nicholas Ohl (Biomedical Engineering).  
2013-2015 Scott Schaper, Mechanical Engineering  
2014 Adam Birnbaum  
2012-2014 Alexandra Faye Salomon, HHMI Mentoring Fellows Program  
2011-2013 Aliza Abraham, Integrated Science Program  
2010-2011 Ethan Coffel, Computer Engineering and Integrated Science Program  
2010 Leland Gossett, Biomedical Engineering (**Scale** project)  
2010 Chris Semple, Biomedical Engineering (**Scale** project)  
2010-2011 Kyle Liske, Mechanical Engineering (**Scale** project)  
2009-2010 Uzair Admani, Biomedical Engineering  
2009-2010 Omar Hassan, Biomedical Engineering  
2009 Aravinda Gunda, SINE Intern, George Washington University  
2008-2009 Jad Carson, Biomedical Engineering  
2008-2009 Benjamin Proznitz, Dept. of Eng Sci and Applied Math  
2007-2008, Jangir Selimkhanov, Dept. of Eng Sci and Applied Math  
2007-2008, Alec Zopf, Dept. of Biomedical Engineering  
2006-2007 Irene Chiang, Dept. Biochemistry, Molecular, and Cell Biology  
2006-2007 Alfred Shoukry, Biomedical Engineering  
2006-2007 Vicky Huang, Biomedical Engineering  
2005-2006 Clif Lin, College of Arts and Science, Northwestern (with T. Kuiken)  
2004-2007 Tiffany Keung, Biomedical Engineering, Northwestern 2003-2004  
2004-2005 Marie Kyle, Mechanical Engineering, Northwestern (with E. Colgate)  
2004-2005 Elana Green, Mechanical Engineering, Northwestern (with E. Colgate)  
2004-2006 Colin Tan, Biomedical Engineering, Northwestern  
2004-2005 Karin Stensvad, Mech Engineering, Washington University (with E. Colgate)  
2004-2005 Beth Lapour, Mechanical Engineering, Northwestern (with E. Colgate)  
2004-2005 Ani Chatterjee, Biomedical Engineering, Northwestern

### TEACHING

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**Teaching-Northwestern University. Courses Developed:**

Risk (DSGN 495, with Michael Rakowitz from Dept of Art Theory and Practice, Cross listed between School of Engineering and Dept of Art Theory and Practice) 2016

Water (DSGN 495, with Michael Rakowitz from Dept of Art Theory and Practice, Cross listed between School of Engineering and Dept of Art Theory and Practice) 2015

Artists & Engineers Collaborate (DSGN 495, with Jeanne Dunning from Dept of Art Theory and Practice, Cross listed between School of Engineering and Dept of Art Theory and Practice) 2014

Computational neuromechanics and neuroethology (BME 461) 2004-present

Neuromechatronics (BME 464) 2004-2013

### Teaching-Northwestern University

Analysis of Biological Systems (BME 306) 2015-present

Design Thinking and Communication (DTC) 2013-present

Professional Essentials (ME 513) 2008-present

“Experimental Engineering” (ME 224) 2007-present

Introduction to Biomechanics (BME 271) 2009-2013

IDEA 298 Faculty Advisor for Submersible Team 2007

“Honors Eng. Analysis 3” 2004-2006

### Other Teaching

Zygon Center for Religion and Science, Chicago IL, Situated Brain and Mind Seminar: “Situated Nervous Systems and Cognition” Feb 18, 2013.

Northwestern University, National High School Institute Cherubs, Theatre Arts Program, guest instructor for “Theatre for Nerds” elective, July 7-8, 2009.

Gulbenkian Research Institute, Portugal, “Normative Theories of Brain Function” Feb 2008

University of Chicago, guest lecturer, Dept. of Philosophy/HIPS, William Wimsatt and John Haugeland, “Boundaries, Modules and Levels” Feb 2006

Guest lecturer, “Animal Behavior” Northwestern University 2004

### Teaching Prior to Northwestern University

University of Illinois, “Neurophysiology Laboratory” (PHYSL 416) 1/97-5/97

University of Illinois, “Topics in Neuroethology” (PHYSL 490) 8/96-12/96

University of Illinois, “Introduction to Neurobiology” (BIO 303) 8/94-12/94

Indiana University, “Introduction to Philosophy” (P100) 1/94-5/94

University of Toronto, “How Computers are Used” (CSC104) 1/91-5/91

Indiana University, “Introduction to Ethics” (P140) 9/92-12/92

University of Toronto, “How Computers are Used” (CSC104) 9/91-12/91

University of Toronto, “Computer Programming” (CSC108) 9/90-12/90

University of Toronto, “Science and Pseudo Science” (PHL272) 1/89-7/89

Confederation College, Thunder Bay ON. Digital Electronics, Programming 1/86-4/86

## SERVICE

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### Memberships

International Society of Neuroethology  
The J.B. Johnston Club for Evolutionary Neuroscience  
Society for Neuroscience  
Institute of Electrical and Electronics Engineers  
American Physical Society

### Scientific Review Panels

NSF Ad-Hoc for Animal Sensation and Movement, and Neural Cluster Program Panels, 2007-present; NSF Neural Cluster Program Panel Meeting, 2008; NSF Animal Sensation and Movement Program Panel Meeting, 2006; MIT Sea Grant College Program, 2006; NIH Sensorimotor Integration Study Section, 2004.

### Conference Organization

Organizer: 10<sup>th</sup> International Symposium on Adaptive Motion of Animals and Machines, 2018 Chicago IL.  
First International Workshop on Robotic Electrolocation, August 3 2012, College Park Maryland.  
International Society for Neuroethology Symposium “Coupled Robot-Animal Systems,” Spain 2010

### Reviewer for the Following *Journals* and Conferences

*Advanced Robotics*  
*Autonomous Robots*  
*Bioinspiration and Biomimetics*  
*Biological Cybernetics*  
*Behavioral and Brain Sciences*  
*Brain, Behavior, and Evolution*  
*Complexity*  
*Current Biology*  
*Frontiers in Behavioral Neuroscience*  
IEEE Conference on Robotics and Automation  
*IEEE Journal of Oceanic Engineering*  
*IEEE Proceedings*  
*IEEE Transactions on Robotics*  
*IEEE Sensors Journal*  
*Integrative and Comparative Biology*  
*International Journal of Robotics Research*  
International Conference on Artificial Neural Networks  
International Congress of Neuroethology

*Journal of Biomechanics*  
*Journal of Comparative Physiology*  
*Journal of Experimental Biology*  
*Journal of the Royal Society Interface*  
*Journal of Visualized Experiments*  
*Nature Communications*  
*Neurocomputing*  
*Physical Biology*  
*PLoS Computational Biology*  
*PLoS Biology*  
*Proceedings of the National Academy of Sciences*  
*Proceedings of the Royal Society B*  
 Robotics Science and Systems  
*Science*

### Current/Past Advisory Boards

2015—subCULTron Advisory Board, European Union (H2020 Project no. 640967), a group of 14 scientists from Italy, Austria, Belgium, Croatia, Germany, and France building a swarm of autonomous underwater robots.

2007-2013 FILOSE Advisory Board Member (of three). FILOSE (Robotic FIsh LOcomotion and SEnsing) is a FP7-ICT-2007-3 STREP research project financed by the European Union 7th Framework Program, headed by the Tallinn University of Technology in Estonia, with partners Riga Technical University of Latvia, the Italian Institute of Technology in Genova, and the Universities of Verona and Bath UK. Web site: [http://www.biorobotics.ttu.ee/tikiwiki\\_filose/tiki-index.php](http://www.biorobotics.ttu.ee/tikiwiki_filose/tiki-index.php).

### University Service

2016- Dept. of Biomedical Engineering, Director of Graduate admissions  
 2015- Northwestern Institute on Complex Systems, neuroscience subgroup lead  
 2015- BME Undergraduate Program Committee, Faculty Community Committee  
 2015- Interviewee for Program Review of the Department of Neurobiology  
 2013- Segal Design Institute, Research Council Executive Committee Member  
 2009-present Tech and Ford Safety Committee, Safety Officer for Department of Biomedical Engineering and Department of Mechanical Engineering  
 2014-2015 Northwestern Neuroscience Proposed Major Steering Committee  
 2011-2013 Faculty Senate representative, Department of Biomedical Engineering  
 Faculty Senate Committee Chair, Secure Faculty Survey  
 2009-2013 Committee on Animal Resources  
 2011 Northwestern Interdepartmental Neuroscience Program Review Committee  
 2009-2010 Freshman Advising  
 2008-2009 BME Admissions Committee  
 NUIN Student Interviews  
 Organized and ran the ME Dept. Professional Skills graduate seminar series



- 2007-2008 Freshman Advising  
ME Control and Manufacturing Search Committee  
Organized and ran the ME Dept. Professional Skills graduate seminar series  
Interdisciplinary Committee on Evolutionary Processes  
NUIN Student Interviews
- 2006-2007 ME Target of Opportunity Ad-hoc Hiring Committee  
Department of Neurobiology and Physiology Hiring Committee  
ME Undergraduate Laboratory Course Renewal Committee  
NUIN Admissions Committee  
Interdisciplinary Committee on Evolutionary Processes
- 2005-2006 Dept. of Neurobiology and Physiology & Department of Physics and Astronomy  
Hiring Interdepartmental Hiring Committee  
Dynamics and Complex Systems IGERT, managed seminar series on the  
Mechanics of Locomotion  
BME Departmental Website Faculty Liaison
- 2004-2005 BME Graduate Student Admissions Committee  
BME Web Site Faculty Liason  
BME/Department of Physical Medicine and Rehabilitation Neural Engineering  
Hiring Committee  
BME/RIC Neural Engineering Hiring Committee  
ME/BME Neural Engineering Hiring Committee  
NUIN Retreat Planning Committee  
Research Data Integration and Assessment System Development Committee
- 2002-2003 Summer Minority Undergraduate Research Program mentor, Caltech

## SELECT MEDIA COVERAGE

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2017 SciTechNow, PBS TV. Interview by Hari Sreenivasan on PNAS study about why fish came on to land 385 million years ago, initial broadcast July 24 2017. <http://www.scitechnow.org/videos/data-reveals-long-ago-fish-made-leap-onto-land/>

2017 Fish Changed in a Surprising Way Before Invading Land. Ed Yong, The Atlantic Online, March 8 2017. <https://www.theatlantic.com/science/archive/2017/03/in-the-invasion-of-land-big-eyes-came-before-strong-legs/518883/>

2017 Why Did Life Move to Land? For the View. Jennifer Ouellette, Quanta Magazine, March 7, 2017. <https://www.quantamagazine.org/why-did-life-move-to-land-for-the-view-20170307/>

2015 ASME Mechanical Engineering Magazine. Ghost Knifefish in the Machine. [https://www.dropbox.com/s/qq7ndhkl3hbfsyd/Ferb15a\\_electrosense\\_ASME.pdf?dl=0](https://www.dropbox.com/s/qq7ndhkl3hbfsyd/Ferb15a_electrosense_ASME.pdf?dl=0)

2015 New York Times Science Take (Video + Article) The Right Ratio to Engineer a Swim. <http://www.nytimes.com/2015/05/11/science/the-right-ratio-to-engineer-a-swim.html>.

2015 Washington Post. How 22 diverse ocean creatures ended up using the same swim stroke. <http://www.washingtonpost.com/news/speaking-of-science/wp/2015/04/28/how-22-diverse-ocean-creatures-ended-up-using-the-same-swim-stroke/>

2015 Los Angeles Times. Would animals swim differently on an alien planet? <http://www.latimes.com/science/sciencenow/la-sci-sn-swimming-animals-convergent-evolution-ocean-bioinspired-alien-20150428-story.html>

2015 PLOS Biology Perspective Convergence on an Optimal Way to Swim, DOI: 10.1371/journal.pbio.1002124. <http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002124>

2015 Journal of Experimental Biology Perspective, Life converges on solutions to swim optimally. <http://jeb.biologists.org/content/218/17/2663.2.full>

2015 CBS. Movements of fish, bats inspire next-gen robots. <http://www.cbsnews.com/news/movements-of-fish-bats-could-inspire-better-robots/>

2014 Entertaining Science—Scientific advisers for films and television help to bring credibility to the screen — and take some tangible and intangible benefits back to the lab. *Nature*, 3 July 2014, vol 511, p. 113-114. <http://www.nature.com/naturejobs/science/articles/10.1038/nj7507-113a>

2014 How Does a Chicken Tell Time? The New Yorker <http://www.newyorker.com/tech/elements/how-does-a-chicken-tell-time>

2014 Electric Eels Use Their Zaps to Remotely Control Prey. *Popular Mechanics*. <http://www.popularmechanics.com/science/animals/a13205/this-is-what-an-electric-eel-shocks-does-17493859/>

2014 Entertaining Science—Scientific advisers for films and television help to bring credibility to the screen — and take some tangible and intangible benefits back to the lab. *Nature*, 3 July 2014, vol 511, p. 113-114.. <http://dx.doi.org/10.1038/nj7507-113a>

2014 BBC TV: Robot builders inspired by animal kingdom. <http://www.bbc.com/news/science-environment-26222542>

2013 PBS Chicago affiliate WTTW Scientific Chicago with Neil Shubin on development of our electric fish robot. <http://chicagotonight.wttw.com/2013/11/26/scientific-chicago-neil-shubin>

2012 Popular Mechanics, “Meet the Scientists who Make Science Believable” Jan 17, 2012. <http://www.popularmechanics.com/culture/movies/a11747/scientific-advisors-to-the-stars/>

2011 New York Times, "A Beijing Exhibition on Art for the 'Post-Human Era', August 11, 2011. <http://www.nytimes.com/2011/08/12/arts/12iht-translife12.html>.

2011 Profile by the National Academy of Science's **Science Entertainment Exchange**, June 2, 2011. <http://bit.ly/j3lcPX>.

2011 Written By, April/May 2011. The science and fiction toybox, by Louise Farr. Magazine article on work with science fiction movie and TV makers by the trade magazine of the writer's guild of America.

2011 Video press release on new fish robot and results published in J. Royal Society Interface (2010), <http://bit.ly/ZKM8h>.

2010 Fast Company. Robotic ghost knifefish swims in every direction, causes brainiacs to high-five. <http://www.fastcompany.com/1718785/robotic-ghost-knifefish-swims-every-direction-causes-brainiacs-high-five-video>

2010 MSNBC. Electric fish could be model for underwater robots. [http://www.nbcnews.com/id/40787244/ns/technology\\_and\\_science-innovation/t/electric-fish-could-be-model-underwater-robots/- .Vgb9prR6ejk](http://www.nbcnews.com/id/40787244/ns/technology_and_science-innovation/t/electric-fish-could-be-model-underwater-robots/- .Vgb9prR6ejk)

2010 Wired Magazine. Black Ghost Knifefish Robot Unmasks Movement Secrets. <http://www.wired.com/2010/12/robot-fish-ribbon-fin/>

2010 National Association of Engineering, Engineering Innovation Podcast and Radio Series. Body Intelligence. Broadcast on WTOP in Washington DC on March 21, 2010. [Does all cleverness and intelligence come from our brains? That may seem logical, but may not be the case.](#)

2010 Interview on Tron and Caprica involvement: Engineering Professor and Caprica Science Consultant Malcolm MacIver. ScriptPhD <http://is.gd/aP2Hk>.

2010 C is for Caprica. Story on involvement with Caprica show. National Academy of Science Science Entertainment Exchange. <http://is.gd/a8j8l>.

2010 Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana Champaign Alumni Profile <http://is.gd/a8iCT>.

2010 Northwestern University News: Robotics Expert Lends a Hand in 'Caprica' <http://is.gd/a8jTI>.

2009 ProPublica: "Stimulus for Cotton Candy, Tango and a Fish Orchestra? Wacky, or Actually Worthy?" <http://is.gd/4O7Vs>

2009 A Shark's Sixth Sense (interview on electroreception in sharks for Shark Week). Chicago Tribune, August 6 2009, <http://tinyurl.com/nfsq9u>, and Feinberg Science and Society featured article <http://tinyurl.com/lahfv5>.

2007 Robotic submersibles take on fish-like sensing abilities. **engadget** technology blog <http://tinyurl.com/37pvm4>.

2007 Electric fields could give subs `fish-like' sense. New Scientist Tech 2007 <http://tinyurl.com/m27oxo>.

2003 Avant science; Artists and scientists both think creatively, so why not match them in projects showcasing new research? In Pasadena, the results have been adventurous. By Suzanne Muchnic *The Los Angeles Times*. Los Angeles, CA, USA, Feb 16 2003. page E.41, <http://tinyurl.com/l3uwbe>.

2003 What Is It Like To Be a Fish? By Margaret Wertheim, *LA Weekly*, Los Angeles, CA, USA. April 11, 2003, <http://tinyurl.com/ku8azp>.

2003 Neuro Art Show: *LA Weekly* Pick of the Week, May 9, 2003, <http://tinyurl.com/mkgaoj>.

2003 'Neuro': Engineering Art and Science. By Lance Carlson, *Art Week*, July/August 2003, p. 24-25, <http://tinyurl.com/l9ee8d>.