BIOGRAPHICAL SKETCH

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NAME: Cowan, Noah

eRA COMMONS USER NAME (credential, e.g., agency login): ncowan1

POSITION TITLE: Professor of Mechanical Engineering

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE (if applicable)	END DATE MM/YYYY	FIELD OF STUDY
Ohio State University, Columbus, OH	BS	03/1995	Electrical Engineering
University of Michigan, Ann Arbor, MI	MS	05/1999	Electrical Engineering
University of Michigan, Ann Arbor, MI	PHD	05/2003	Electrical Engineering

A. Personal Statement

My research is devoted to understanding navigation and control in machines and animals. My laboratory conducts experiments and computational analyses on both biological and robotic systems, with focus on applying concepts from dynamical systems and control theory to garner new insights into the principles that underlie neural computation. This research program has been recognized by a Presidential Early Career Award in Science and Engineering (PECASE) and a James S. McDonnell Complex Systems Scholar award.

A central component of my research over the last several years has been a productive, multidisciplinary collaboration with faculty in the Neuroscience Department at JHU. We have jointly advised several PhD students and postdocs, including two trainees that are now assistant professors with independent research laboratories.

Ongoing and recently completed awards that I wish to highlight include:

R01 NS102537
N. Cowan (PI) Role: Co-Investigator 8/1/2017 – 8/31/2028
A Control Theoretic Approach to Addressing Hippocampal Function

R01 MH118926
J. Knierim, N. Cowan, K. Hedrick, K. Zhang (PIs) 07/1/2018 – 06/30/2023
CRCNS: Dynamics of Gain Recalibration in the Hippocampal-Entorhinal Path Integration System

72929-EG-MUR (Army Research Office)
D. Koditschek (PI) JHU PI and Role: Project Co-Leader 06/01/2018 – 09/01/2024
Science of Embodied Innovation, Learning and Control

72929-EG-MUR (Office of Naval Research)
Control and Learning Enabled Verifiable Robust AI (CLEVR-AI)
M. Sznaier (PI). Role: JHU PI and Project Co-Leader 06/01/2021 – 05/31/2026

Prof. Cowan's multidisciplinary, collaborative research program is articulated in three review papers:

1. Swensen JP, Lin M, Okamura AM, Cowan NJ. Torsional dynamics of steerable needles: modeling and fluoroscopic guidance. IEEE Trans Biomed Eng. 2014 Nov;61(11):2707-17. PubMed Central

PMCID: PMC5541402.

2. Kallem V, Chang DE, Cowan NJ. Task-Induced Symmetry and Reduction with Application to Needle Steering. IEEE Trans Automat Contr. 2010;55(3):664-673. PubMed Central PMCID: PMC2871331.
3. Reed KB, Okamura AM, Cowan NJ. Modeling and control of needles with torsional friction. IEEE Trans Biomed Eng. 2009 Dec;56(12):2905-16. PubMed Central PMCID: PMC2859043.
4. Webster RJ, Kim JS, Cowan NJ, Chirikjian GS, Okamura AM. Nonholonomic Modeling of Needle Steering. The International journal of robotics research. 2006 May; 25(5-6):509–525. DOI: 10.1177/0278364906065388

B. Positions, Scientific Appointments and Honors

Positions and Scientific Appointments

2025 -	Secondary Appointment in Neuroscience, Johns Hopkins University, Baltimore
2017 -	Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, MD
2013 - 2018	Deputy Director, Laboratory for Computational Sensing and Robotics, Johns Hopkins University, Baltimore, MD
2010 -	Secondary Appointment in Elec. and Comp. Eng., Johns Hopkins University, Baltimore, MD
2010 - 2017	Associate Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, MD
2003 -	Secondary Appointment in Computer Science, Johns Hopkins University, Baltimore, MD
2003 - 2010	Assistant Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, MD

Honors

2024	Fellow, IEEE
2023	Discovery Award, Johns Hopkins University
2016	Discovery Award, Johns Hopkins University
2015	Discovery Award, Johns Hopkins University
2014	The Dunn Family Award, conferred for having . . . an extraordinarily positive impact upon the lives of one or more undergraduate students . . . , Johns Hopkins University
2012	Scholar Award in Complex Systems Science, James S. McDonnell Foundation
2010	Presidential Early Career Award in Science and Engineering (PECASE), National Office of Science and Technology Policy
2010	Invited Speaker, US and European National Academies of Engineering, Frontiers of Engineering Workshop, Cambridge, England
2009	CAREER Award, National Science Foundation
2003	W. H. Huggins Excellence in Teaching Award, Johns Hopkins University
2000	Rackham Doctoral Fellowship, University of Michigan
2000	Best Student Paper Finalist, Conference on Decisions and Controls
1995	Summa Cum Laude, Ohio State University

C. Contribution to Science

1. *A Control Theoretic Approach to Addressing Hippocampal Function.* Spatially selective cells of the rodent hippocampal formation form an ideal model system for investigating the interaction between external sensory input and internal neural dynamics in the formation of high-order, cognitive representations. These spatially selective cells are controlled by external sensory features, such as salient local and global landmarks and environmental boundaries. In collaboration with James Knierim's laboratory at Johns Hopkins, we constructed a virtual reality apparatus that allows an

unprecedented level of dynamic control of visual input to place cells, grid cells, and HD cells during naturalistic locomotion. Furthermore, our use of control theory to drive experimental design, analysis, and interpretation is offering new insights that are not obtained through traditional neurophysiological approaches alone.

   a. Madhav MS, Jayakumar RP, Li BY, Lashkari SG, Wright K, Savelli F, Knierim JJ, Cowan NJ. Control and recalibration of path integration in place cells using optic flow. Nat Neurosci. 2024 Aug;27(8):1599-1608. PubMed Central PMCID: PMC11563580.
   b. Secer,Gorkem,, Knierim,James,J, Cowan,Noah,J. Continuous Bump Attractor Networks Require Explicit Error Coding for Gain Recalibration. bioRxiv [Preprint]. 2024 March 20. Available from: https://www.biorxiv.org/content/10.1101/2024.02.12.579874v2 DOI: 10.1101/2024.02.12.579874
   c. Madhav MS, Jayakumar RP, Lashkari SG, Savelli F, Blair HT, Knierim JJ, Cowan NJ. The Dome: A virtual reality apparatus for freely locomoting rodents. J Neurosci Methods. 2022 Feb 15;368:109336. PubMed Central PMCID: PMC9178503.
   d. Jayakumar RP, Madhav MS, Savelli F, Blair HT, Cowan NJ, Knierim JJ. Recalibration of path integration in hippocampal place cells. Nature. 2019 Feb;566(7745):533-537. PubMed Central PMCID: PMC6629428.

2. *Neuromechanics of locomotion in the weakly electric glass knifefish.* Weakly electric fish have been a model system in systems neuroscience for about 40 years. Most investigations center on control of electric organ discharge as a function of electro-social interactions with conspecifics. Since 2007 my lab, in collaboration with Dr. Eric Fortune, has taken advantage of the fact that these animals are also adept swimmers. We have investigated the interplay between mechanics and sensing for multisensory control of locomotion, and have discovered that electric fish alter their patterns of movement in relation to the "predictability" of the stimulus movement. We have also discovered how the generation and modulation of mutually opposing forces enable animals to obtain both stability and maneuverability during locomotion.
   a. Biswas D, Lamperski A, Yang Y, Hoffman K, Guckenheimer J, Fortune E, Cowan N. Mode switching in organisms for solving explore-versus-exploit problems. Nature Machine Intelligence. 2023 October 26; 5(11):1285-1296. Available from: https://www.nature.com/articles/s42256-023-00745-y DOI: 10.1038/s42256-023-00745-y
   b. Biswas D, Arend LA, Stamper SA, Vágvölgyi BP, Fortune ES, Cowan NJ. Closed-Loop Control of Active Sensing Movements Regulates Sensory Slip. Curr Biol. 2018 Dec 17;28(24):4029-4036.e4. PubMed PMID: 30503617.
   c. Sefati S, Neveln ID, Roth E, Mitchell TR, Snyder JB, Maciver MA, Fortune ES, Cowan NJ. Mutually opposing forces during locomotion can eliminate the tradeoff between maneuverability and stability. Proc Natl Acad Sci U S A. 2013 Nov 19;110(47):18798-803. PubMed Central PMCID: PMC3839770.
   d. Roth E, Zhuang K, Stamper SA, Fortune ES, Cowan NJ. Stimulus predictability mediates a switch in locomotor smooth pursuit performance for Eigenmannia virescens. J Exp Biol. 2011 Apr 1;214(Pt 7):1170-80. PubMed PMID: 21389203.

3. *Antenna-mediated control of rapid locomotion in cockroaches.* The American cockroach is among the fastest terrestrial animals relative to their body size, and can perform extraordinarily rapid control of their locomotion in complete darkness using feedback from a pair of head-mounted antennae. Unlike whiskers, insect antennae are highly innervated structures that provide tactile and strain (bending) information using sensory receptors along the length of the antennal flagellum. Using a combination of biological and robotic experimentation, together with dynamical systems analysis, we have examined antennal navigation and control at all levels of organization, from the task-level control algorithms necessary for rapid wall following, down to the roles of tiny hair-like spines on the flagellum, ultimately determining what the control algorithms are, and how they are instantiated via neuromechanical processing in the antenna itself.
   a. Mongeau JM, Demir A, Dallmann CJ, Jayaram K, Cowan NJ, Full RJ. Mechanical processing via passive dynamic properties of the cockroach antenna can facilitate control during rapid running. J

Exp Biol. 2014 Sep 15;217(Pt 18):3333-45. PubMed PMID: 25013115.

b. Mongeau JM, Demir A, Lee J, Cowan NJ, Full RJ. Locomotion- and mechanics-mediated tactile sensing: antenna reconfiguration simplifies control during high-speed navigation in cockroaches. J Exp Biol. 2013 Dec 15;216(Pt 24):4530-41. PubMed PMID: 24307709.

c. Jusuk Lee, Sponberg S, Loh O, Lamperski A, Full R, Cowan N. Templates and Anchors for Antenna-Based Wall Following in Cockroaches and Robots. IEEE Transactions on Robotics. 2008 February; 24(1):130-143. Available from: http://ieeexplore.ieee.org/document/4456752/ DOI: 10.1109/TRO.2007.913981

d. Cowan N, Lee J, Full R. Task-level control of rapid wall following in the American cockroach. Journal of Experimental Biology. 2006 May 01; 209(9):1617-1629. Available from: https://journals.biologists.com/jeb/article/209/9/1617/16951/Task-level-control-of-rapid-wall-following-in-the DOI: 10.1242/jeb.02166

4. *Navigation and control of steerable needles and active cannulas.* The ability to navigate inside the human body is critical for minimally invasive procedures. My laboratory co-developed, patented, and licensed two technologies to achieve this. First, we developed a new class of steerable needles that derive steerable due to the asymmetry of cutting forces at the tip. My laboratory developed the state-of-the art models for these systems and developed new approaches to image-guided navigation and control. Second, we developed a new class of "active cannulas" that are flexible, pre-curved continuum robots. These active cannulas do not rely on "push-pull" cables or other complicated mechanisms for articulation, but instead exploits the interactions of a nested set of, pre-shaped, telescoping superelastic tubes that form the backbone. For these two technologies we made critical contributions to the mathematical modeling, analysis, and control.
   a. Swensen JP, Lin M, Okamura AM, Cowan NJ. Torsional dynamics of steerable needles: modeling and fluoroscopic guidance. IEEE Trans Biomed Eng. 2014 Nov;61(11):2707-17. PubMed Central PMCID: PMC5541402.
   b. Kallem V, Chang DE, Cowan NJ. Task-Induced Symmetry and Reduction with Application to Needle Steering. IEEE Trans Automat Contr. 2010;55(3):664-673. PubMed Central PMCID: PMC2871331.
   c. Reed KB, Okamura AM, Cowan NJ. Modeling and control of needles with torsional friction. IEEE Trans Biomed Eng. 2009 Dec;56(12):2905-16. PubMed Central PMCID: PMC2859043.
   d. Webster RJ, Kim JS, Cowan NJ, Chirikjian GS, Okamura AM. Nonholonomic Modeling of Needle Steering. The International journal of robotics research. 2006 May; 25(5-6):509–525. DOI: 10.1177/0278364906065388
5. *Visual representations and control of 6D motion in robotics and neuroscience.* A central thread of my research involves the complex geometric relationship between 6D motions (i.e., "x,y,z, roll, pitch, yaw") in 3D space and the movement of features on a 2D image (retina or camera imager). My earliest publications, starting with my PhD work, described the first “global” (in a precise mathematical sense) representation of 6D rigid motion using its image-space coordinates. This work has transitioned to applications to biomedicine (image guidance for medical interventions) and both basic neuroscience (representing 3D rotations in the caudal intraparietal area in the rhesus macaque) and applied neuroscience (invention of a new technology for 6D head tracking).
   a. Vagvolgyi BP, Jayakumar RP, Madhav MS, Knierim JJ, Cowan NJ. Wide-angle, monocular head tracking using passive markers. J Neurosci Methods. 2022 Feb 15;368:109453. PubMed Central PMCID: PMC8857048.
   b. Rosenberg A, Cowan NJ, Angelaki DE. The visual representation of 3D object orientation in parietal cortex. J Neurosci. 2013 Dec 4;33(49):19352-61. PubMed Central PMCID: PMC3850047.
   c. Kallem V, Cowan N. Image Guidance of Flexible Tip-Steerable Needles. IEEE Transactions on Robotics. 2009 February; 25(1):191-196. Available from: http://ieeexplore.ieee.org/document/4752793/ DOI: 10.1109/TRO.2008.2010357; NIHMSID: NIHMS192987

d. N. J. Cowan, J. D. Weingarten, D. E. Koditschek. Visual servoing via navigation functions. IEEE Transactions on Robotics and Automation. 2002; 18(4):521-533. DOI: 10.1109/TRA.2002.802202