

Avik De

Co-founder & CTO Ghost Robotics, Postdoc (University of Pennsylvania)

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Education

Postdoctoral fellow. University of Pennsylvania, Philadelphia, PA. Advisor: Dr. Daniel E. Koditschek	2017—now
Ph.D. University of Pennsylvania, Philadelphia, PA. Advisor: Dr. Daniel E. Koditschek	2010—17
M.S. (Mech Engg), B.S. (Engg Mech), B.S. (Appl Math). Johns Hopkins Univ, Baltimore, MD. Advisors: Dr. Noah J. Cowan (research), Dr. Alison Okamura (academic); GPA: 3.96/4.00	2006—10

Research areas & projects (publications list below)

Steady-state legged behaviors. Reactive gaits (tailed and monopodal hopping, quadrupedal bounding, pronking, trotting, pacing, and walking, bipedal walking) created from template compositions; reactive obstacle avoidance, stair-climbing, stepping stones.	2013—now
Transitional legged behaviors. Leaping using a leg and a tail; tailed inertial reorientation	2014—now
Applied dynamical systems. Interpret high-DOF coupled mechanical systems as coupled oscillators, developed a hybrid systems extension to dynamical averaging, use it to formally analyze stability of composed dynamical systems	
Design. Principles for direct-drive legged robot design; hardware design of a family of direct-drive robots, including complete design of Jerboa, Delta hopper, and partial design of Minitaur; motor and gearbox selection for steady and transient loads; electronics, firmware, base software and system architecture for high-bandwidth, high-transparency platforms spun off into Ghost Robotics.	2012—now
Sensorimotor loops (servoing). “Active antenna”-based wall following; active visual servoing	2012—2013
Bayesian estimation. Proof of convergence of approximate Bayesian estimation using a finite parameterization of posterior belief state; SLAM on graphs	2007—2013
Paddle juggling. Analysis of the role of feedback in human paddle juggling	2009—2010

Work experience (excluding teaching)

Ghost Robotics Corp. Co-founder & CTO. Co-founded a company commercializing legged robots; current customers include top universities (CMU, Caltech, ...), companies (Google, DeepMind), as well as projects with DoD, US SOCOM. Sales ~ US\$1M/yr. Responsibilities include assembling an engineering team starting from the two co-founders to 10+, gait and behavior control algorithms for robust deployment, architecting and implementing the electrical/computing subsystem (comprised of mass-manufacturable custom electronics), firmware and low-level software. YouTube , Twitter .	2015—now
LIMBS lab (Noah Cowan), JHU. Undergrad research assistant: neuromechanical control of juggling; SLAM on graphs. This part-time research resulted in a conference paper (WAFR 2008), a master’s thesis, and a 3 rd author journal paper.	2007—10
Advanced Academic Programs, JHU. Web/database developer (Coldfusion/SQL).	2006—10
Academic Advising, JHU. Tutor (Physics I/II, Calculus I/II/III).	2007—08
Residential Life, JHU. Resident advisor.	2008—10

Honors and awards

Best Doctoral Dissertation Award for the 2017-2018 Academic Year. UPenn Electrical and Systems Engineering dept.	2018
Best Reviewer Award. Awarded at ICRA 2018.	2018
James S. McDonnell Postdoctoral Fellowship Winner. \$200,000 award for 2-3 years.	2017
Robert George Gerstmeier Award. For academic achievement (JHU Mech. Engg. Department)	2008—09
Provost’s Undergraduate Research Award. For summer research (JHU)	2008—09
Tau Beta Pi, Pi Tau Sigma Engg. honor societies. Inductee (JHU)	2008
International Scholarship. Merit-based full-tuition scholarship (JHU)	2006—10

Invited talks (excluding conference talks)

TBD — ACC 2019 workshop “Challenges and Solutions for Legged Robotics”	July 2019
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TBD -- ICRA 2019 workshop " Towards Real-World Deployment of Legged Robots "	May 2019
Template Composition for Synthesis of New Behaviors from Simpler Constituents -- IROS 2018 template-based control workshop	Oct 2018
Tail design and control for a tail- and hip-energized and -stabilized bipedal hopping robot -- RSS 2018 workshop on " Unusual appendages: novel, multi-modal, or multi-functional uses for limbs, tails, and other body parts "	July 2018
Toward robust locomotion subject to variations in robot scale, mass, payload, and environmental conditions -- ICRA 2018 multilegged robots workshop	May 2018
Platform design using dynamic motor, electronics, and transmission models -- ICRA 2018 actuator workshop	May 2018
Modular hopping and running (for biologists and engineers). UC Berkeley biomechanics seminar	Oct 2017
Stable hopping and running from compositions of dynamical primitives. UMichigan, JHU	Jun 2017
Anchored Behaviors from Template Compositions. CMU bipedal seminar; UW seminar	Feb 2017
Mechanically Simple, Behaviorally Versatile Quadrupeds. (with G. Kenneally) TRI (Palo Alto, CA), Google (Mountain View)	Feb 2017
Sequential, Parallel and Symbolic Compositions. UPenn ESE PhD Colloquium (Fall 2015)	2015
Anchor synthesis via template composition. AMAM 2015 in Boston, MA.	2015

Activities, teaching, and service

Reviewer. IJRR, Bioinspiration & Biomimetics, Automatica, T/RO, RA/L, European Journal of Physics, Control Engineering Practice, ICAR, ICHR, ICRA, IFACWC, IROS, SYROCO, WAFR, MCA	
Mentoring. Mentored undergraduate, masters, and junior PhD students to write papers accepted to ICRA/IROS	2013—18
UPenn guest lecturer. ESE 512 (graduate dynamical systems), MEAM 517 (Control and Optimization with Applications in Robotics), MEAM 520 (Intro to Robotics)	2017—now
UPenn/Coursera instructor. Robotics specialization instructor for Mobility, Capstone courses; developed curriculum including topics like how animals and robots are designed and how they move, linearized control and balancing a mobile inverted pendulum	2016
UPenn TA. TA for ESE 201 (undergraduate dynamical systems), ESE 512 (graduate dynamical systems)	2011—12
Outreach. Two-time volunteer / judge at Penn First Lego League (FLL)	2014—16
Animal welfare. Volunteer at Philadelphia Animal Welfare Society (PAWS); cat fostering	2014—now
Hopkins Baja, JHU. Team captain of an engineering design team creating a single-seat offroad vehicle for an SAE-organized collegiate competition; suspension and steering design lead	2006—10
JH Math Club, JHU. Part of JHU Putnam team; contributed problems to JH math tournament for HS students	2006—09
ASME chapter, JHU. Secretary/treasurer	2006—10

Skills

Electrical. PCB schematic&layout (2/4-layer boards); high-power electronics including brushless motor controllers capable of 1.5KW (continuous), >10KW (peak); versatile Cortex A9/M4 hybrid architecture mainboards for robot control with motor comms, logging, IMU, power distribution, operator control.
Firmware. Experience designing and implementing multi-processor real-time robotic control systems; created an Arduino-like set of libraries for STM32F3/4 microcontrollers (open-source "Koduino" repository); extensive experience with Cortex-M4 microcontrollers (timers, communication interfaces, DMA, ...); communication protocols (EtherCAT, Ethernet, USB, RS485 9-bit addressing multiprocessor communication, USART, SPI, I2C); RT Linux; advanced motor control (FOC, field-weakening, etc.).
Software. Architecture and implementation of Ghost Robotics SDK—a flexible robot control platform for controlling multi-jointed multi-limbed systems on platforms from microcontrollers to multi-core processors and simulation environments.
Mechanical. CAD (SolidWorks); overall design of the Penn Jerboa and Delta Hopper robots; designed a lightweight 2DOF spherical joint for Jerboa tail using parallel motors at the base and a linkage; designed a 3DOF parallel leg for Delta hopper; designed chassis, suspension, and steering for a single-seat 200 kg Baja SAE offroad vehicle.

Publications

Journal

A. De and D. E. Koditschek, "Vertical hopper compositions for reflexive and feedback-stabilized quadrupedal bounding, pacing, pronging, and trotting," <i>The International Journal of Robotics Research</i> , vol. 37, no. 7, pp. 743–778, 2018.	2018
A. De , S. A. Burden and D. E. Koditschek, "A hybrid dynamical extension of averaging and its application to the analysis of legged gait stability," <i>The International Journal of Robotics Research</i> , vol. 37, no. 2–3, pp. 266–286, 2018.	2018

G. Kenneally, **A. De**, and D. E. Koditschek, "Design Principles for a Family of Direct-Drive Legged Robots," IEEE Robotics and Automation Letters, vol. 1, no. 2, pp. 900–907, Jul. 2016. 2016

M. M. Ankarali, H. T. Sen, **A. De**, A. M. Okamura, and N. Cowan, "Haptic Feedback Enhances Rhythmic Motor Control By Reducing Variability, Not Convergence Rate," Journal of Neurophysiology, p. jn.00140.2013. 2013

Conference

A. Shamsah, **A. De**, and D. E. Koditschek, "Analytically-Guided Design of a Tailed Bipedal Hopping Robot," in IROS 2018 2018

V. Vasilopoulos, O. Arslan, **A. De**, and D. E. Koditschek, "Sensor-Based Legged Robot Homing Using Range-Only Target Localization," in ROBIO 2017 2017

G. Wenger, **A. De**, and D. E. Koditschek, "Frontal plane stabilization and hopping with a 2DOF tail," in Intelligent Robots and Systems (IROS), 2016 IEEE/RSJ International Conference on, 2016, pp. 567–573. 2016

T. T. Topping, V. Vasilopoulos, **A. De**, and D. E. Koditschek, "Towards bipedal behavior on a quadrupedal platform using optimal control," in SPIE 9837, Unmanned Systems Technology XVIII, 2016, p. 98370H. 2016

A. L. Brill, **A. De**, A. M. Johnson and D. E. Koditschek, "Tail-Assisted Rigid and Compliant Legged Leaping," in 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems, Sep, 2015. 2015

A. De and D. E. Koditschek, "Averaged Anchoring of Decoupled Templates in a Tail-Energized Monoped, 2015 International Symposium on Robotics Research, Sep, 2015. 2015

A. De and D. E. Koditschek, "Parallel composition of templates for tail-energized planar hopping," in Robotics and Automation (ICRA), 2015 IEEE International Conference on, 2015, pp. 4562–4569 2015

A. De and D. E. Koditschek, "The Penn Jerboa: A Platform for Exploring Parallel Composition of Templates," arXiv:1502.05347 [cs.RO] 2015

A. De, K. S. Bayer, and D. E. Koditschek, "Active sensing for dynamic, non-holonomic, robust visual servoing," in Robotics and Automation (ICRA), 2014 IEEE International Conference on, 2014, pp. 6192–6198 2014

A. De, A. Ribeiro, W. Moran, and D. E. Koditschek, "Convergence of Bayesian Histogram Filters for Location Estimation," in Proceedings of the 2013 IEEE Intl. Conference on Decision and Control, 2013. 2013

A. De and D. E. Koditschek, "Toward dynamical sensor management for reactive wall-following," in Robotics and Automation (ICRA), 2013 IEEE International Conference on, 2013, pp. 2400–2406. 2013

A. De, G. Lynch, A. Johnson, and D. Koditschek, "Motor sizing for legged robots using dynamic task specification," in 2011 IEEE Conference on Technologies for Practical Robot Applications (TePRA), pp. 64–69 2011

A. De, J. Lee, N. Keller, and N. J. Cowan, "Toward SLAM on Graphs," in Algorithmic Foundation of Robotics VIII, vol. 57, G. S. Chirikjian, H. Choset, M. Morales, and T. Murphey, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 631–645 2009

Abstracts, Posters, Workshops, and Technical Reports

A. De and D. E. Koditschek, "Hybrid averaging shows that within-stance symmetry helps mitigate coupling interactions between degrees of freedom in a sagittal 2DOF monoped and 3DOF biped," Dynamic Walking 2017. 2017

A. De and D. E. Koditschek, "Reactive coordination: stabilizing common quadrupedal gaits without CPGs," [Sixth Annual Winter Workshop on Neuromechanics and Dynamics of Locomotion](#), Tulane University – New Orleans, Louisiana, January 19 – 20, 2017 2017

G. Kenneally, **A. De** and D. E. Koditschek, "Design Principles for a Family of Direct-Drive Legged Robots," RSS [Workshop on Miniature Legged Robots](#), July 2015. 2015

G. J. Wenger, **A. De** and D. E. Koditschek, "Roll Stabilization on a Tailed Biped," [RSS workshop on robotic uses for tails](#), July, 2015 2015

A. De and D. E. Koditschek, "[The Penn Jerboa: A Platform for Exploring Parallel Composition of Templates](#)," Technical report, 2015 2015

A. De, A. M. Johnson and D. E. Koditschek, "Planar Hopping with a Leg and a Tail," Dynamic Walking, June, 2014 2014

Theses

A. De, "[Modular Hopping and Running via Parallel Composition](#)" Ph.D. thesis, University of Pennsylvania. 2017

A. De, "[Neuromechanical Control of Paddle Juggling](#)," Master's thesis, Johns Hopkins University. 2010