

NEEL DOSHI

Postdoctoral Associate

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EDUCATION

Harvard University Doctor of Philosophy, Engineering Sciences Thesis: <i>Model-based design, control, and planning for legged microrobots</i> Advisors: Robert J. Wood & Scott Kuindersma	Cambridge, MA <i>May 2019</i>
Harvard University Master of Science, Engineering Sciences	Cambridge, MA <i>Nov 2015</i>
University of Pennsylvania Master of Science, Robotics	Philadelphia, PA <i>May 2013</i>
University of Pennsylvania Bachelor of Science, <i>summa cum laude</i> , Mechanical Engineering Minors: Electrical Engineering, Mathematics	Philadelphia, PA <i>May 2012</i>

PROFESSIONAL EXPERIENCE

Massachusetts Institute of Technology <i>Postdoctoral Researcher, The MCube Lab</i>	Cambridge, MA <i>Apr 2019-Present</i>
<ul style="list-style-type: none">Combining mechanics and optimization to develop models and algorithms that enable efficient planning and control tools for contact-rich robotic manipulation.Designing robotic hands and fingers that leverage switchable adhesion to simplify planning and control and facilitate dexterous manipulation.	
Harvard University <i>Doctoral Student, Harvard Microrobotics Laboratory</i>	Cambridge, MA <i>Sep 2013-Mar 2019</i>
<ul style="list-style-type: none">Used optimization to develop physics-based design, planning, and control tools for legged microrobots to execute dynamic behaviors on the Harvard Ambulatory Microrobot (HAMR).Used laminate manufacturing processes to design and fabricate robot-feet that enable novel locomotion modalities, including climbing and swimming, for HAMR.	
University of Pennsylvania <i>Research Assistant, ModLab</i>	Philadelphia, PA <i>Mar 2012-Jul 2013</i>
<ul style="list-style-type: none">Developed a fast-analytic simulator to resolve the hydrodynamics of a large (100+ node) elastically linked modular sea-base in support of DARPA research.	
NASA Goddard Space Flight Center <i>Robotics Intern, NASA-GSFC</i>	Greenbelt, MD <i>Summer 2011</i>
<ul style="list-style-type: none">Designed, analyzed, and manufactured a protective thermal enclosure for the electronics of Grover 2, an autonomous rover designed to explore Greenland's ice sheets.	
University of Pennsylvania <i>Research Assistant, ModLab</i>	Philadelphia, PA <i>Summer 2010</i>
<ul style="list-style-type: none">Designed and manufactured a passive compliant gripper for a modular robot (CKbot). Constructed compliant fiberglass legs and characterized their bulk mechanical properties.	

AWARDS AND RECOGNITIONS

RA-L Best Paper Award for J9	<i>Jun 2020</i>
Intelligence Community Postdoctoral Research Fellowship	<i>Oct 2019</i>
2nd Prize, IBM Research: ISS Meets AI	<i>Sep 2019</i>
Finalist, Best Conference Paper Award (ICRA) for J3	<i>Jun 2018</i>
Finalist, Best Conference Paper Award (IROS) for C7	<i>Sep 2017</i>
Certificate of Distinction in Teaching	<i>May 2015</i>
Best Automation Paper (ICRA) for C1	<i>Jun 2014</i>
National Defense Science and Engineering Graduate (NDSEG) Fellowship	<i>Apr 2014</i>
Honorable Mention, National Science Foundation (NSF) Graduate Fellowship	<i>Apr 2014</i>
William K. Gemmill Memorial Award for Senior Design Project	<i>May 2012</i>
Dean's list	<i>Spring 2010-Spring 2012</i>

REFEREED JOURNAL PUBLICATIONS (J)

- J10. H. McClintock*, **N. Doshi***, A.I. Rabago*, J.C. Weaver, K. Jayaram, R.J. Wood, and J.T.B. Overvelde, A fabrication strategy for re-configurable millimeter-scale metamaterials. *Advanced Functional Materials*, 2021, 2103428.
- J9. Y. Chen, **N. Doshi**, and R. J. Wood. Inverted and inclined climbing through capillary adhesion in a quadrupedal insect-scale robot. In *IEEE Robotics and Automation Letters*, vol. 5, no. 3, pp. 4820-4827, 2020.
Presented at IROS 2020; RA-L Best Paper Award
- J8. **N. Doshi***, K. Jayaram*, S. Castellanos, S. Kuindersma, and R.J. Wood, Effective locomotion at multiple stride frequencies using proprioceptive feedback on a legged microrobot. *Bioinspiration & Biomimetics*, vol. 14, no. 5, 2019.
- J7. Z. Manchester, **N. Doshi**, R. J. Wood, and S. Kuindersma, Contact-Implicit trajectory optimization using variational integrators. *The International Journal of Robotics Research*, 2019.
- J6. S. D. Rivaz, B. Goldberg, **N. Doshi**, K. Jayaram, J. Zhou, and R. J. Wood, Inverted and vertical climbing of a quadrupedal microrobot using electroadhesion. *Science Robotics*, 3: eaau3038, 2018.
Altmetric: 169
- J5. Y. Chen, **N. Doshi**, B. Goldberg, H. Wang, and R. J. Wood, Controllable water surface to underwater transition through electrowetting in a hybrid terrestrial-aquatic microrobot. *Nature Communications* 9, no. 1 (June 27, 2018): 2495.
Altmetric: 674
- J4. K. Jayaram, N. Jafferis, **N. Doshi**, B. Goldberg, and R.J. Wood. Concomitant sensing and actuation for piezoelectric microrobots. *Smart Materials and Structures*, vol. 27, no. 6, p.065028, 2018.
- J3. B. Goldberg*, R. Zufferey*, **N. Doshi**, E.F. Helbling, G. Whittredge, M. Kovac, R.J. Wood, Power and Control Autonomy for High-Speed Locomotion With an Insect-Scale Legged Robot. *IEEE Robotics and Automation Letters*, vol. 3, no. 2, p. 987-993, 2018.
Presented at ICRA 2018; Finalist, Best Conference Paper

*contributed equally

REFEREED JOURNAL PUBLICATIONS CONT. (J)

- J2. H. McClintock*, F. Z. Temel*, **N. Doshi**, J.-S. Koh, and R. J. Wood, The milliDelta: a high-bandwidth, high-precision, millimeter-scale Delta robot. *Science Robotics*, 3: eaar3018, 2018.
Altmetric: 187
- J1. B. Goldberg, **N. Doshi**, K. Jayaram, and R.J. Wood, Gait studies for a quadrupedal microrobot reveal contrasting running templates in two frequency regimes. *Bioinspiration & Biomimetics*, vol. 12, no. 4, 2017.

REFEREED CONFERENCE PUBLICATIONS (C)

- C11. J. Gruenstein, T. Chen, **N. Doshi**, and Pulkit Agrawal, Residual Model Learning for Microrobot Control. In *Proceedings of the International Conference on Robotics and Automation (ICRA)*, Xian, China, June 2021.
- C10. I. H. Taylor, N. Chavan-Dafle, G. Li, **N. Doshi.**, and A. Rodriguez, PnuGrip: An active two-phase gripper for dexterous manipulation. In *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, Las Vegas, USA, October 2020.
- C9. **N. Doshi**, F.R. Hogan, and A. Rodriguez, Hybrid differential dynamic programming for planar manipulation primitives. In *Proceedings of the International Conference on Robotics and Automation (ICRA)*, Paris, France, June 2020.
- C8. **N. Doshi**, K. Jayaram, B. Goldberg, Z. Manchester, R.J. Wood, and S. Kuindersma, Contact-implicit optimization of locomotion trajectories for a quadrupedal microrobot. *Robotics: Science and Systems (RSS)*, Pittsburgh, USA, July 2018.
- C7. B. Goldberg, **N. Doshi**, K. Jayaram, J.-S. Koh, and R.J. Wood. A high speed motion capture method and performance metrics for studying gaits on an insect-scale legged robot. In *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, Vancouver, Canada, September 2017.
Finalist, Best Conference Paper
- C6. B. Goldberg, **N. Doshi**, and R.J. Wood, High speed trajectory control using an experimental maneuverability model for an insect-scale legged robot. In *Proceedings of the International Conference on Robotics and Automation (ICRA)*, Singapore, June 2017.
- C5. **N. Doshi**, K. Jayaram, B. Goldberg, and R.J. Wood, Phase control for a legged microrobot operating at resonance. In *Proceedings of the International Conference on Robotics and Automation (ICRA)*, Singapore, June 2017.
- C4. **N. Doshi**, B. Goldberg, R. Sahai, N. Jafferis, D. Aukes, and R.J. Wood, Model driven design for flexure-based microrobots. In *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, Hamburg, Germany, September 2015.
- C3. R. Brühwiler, B. Goldberg, **N. Doshi**, O. Ozcan, N. Jafferis, M. Karpelson, and R.J. Wood, Feedback control of a legged microrobot with on-board sensing. In *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, Hamburg, Germany, September 2015.
- C2. B. Seitz, B. Goldberg, **N. Doshi**, O. Ozcan, D. Christensen, M. Cutkosky, and R.J. Wood, Bio-inspired mechanisms for inclined locomotion in a legged insect-scale robot. In *Proceedings of the International Conference on Robotics and Biomimetics (ROBIO)*, Bali, Indonesia, December 2014.
- C1. I. O'Hara, J. Paulos, J. Davey, N. Eckenstein, **N. Doshi**, T. Tosun, J. Greco, J. Seo, M. Turpin, V. Kumar, and M. Yim, Self-assembly of a swarm of autonomous boats into floating structures. In *Proceedings of the International Conference on Robotics and Automation (ICRA)*, Hong Kong, China, May 2014.
Best Automation Paper Award 2014

POSTERS, WORKSHOPS, AND ABSTRACTS (M)

- M14. **N. Doshi***, O.T. Taylor*, A. Rodriguez, Indirect Force Control for Manipulating Unknown Planar Objects. In *IROS 2021 Workshop on Variable Impedance Robotics Skills: Challenges and Opportunities*, Prague, Czech Republic, Oct 2021.
- M13. **N. Doshi**, Robotic manipulation of unknown objects with environmental contacts. In *Intelligence Community Academic Research Symposium*, National Academy of Sciences, Washington D.C., USA, September 2021.
- M12. **N. Doshi**, and A. Rodriguez, Towards Real-time Planning of Hybrid Manipulation Primitives with Differential Dynamic Programming. In *RSS 2021 Workshop on 2021 Workshop on Software Tools for Real-Time Optimal Control*, Virtual, July 2021.
- M11. **N. Doshi**, O.T. Taylor, and A. Rodriguez, Pivoting a partially unknown object about an environmental contact, In *IROS 2020 Workshop on Why robots fail to grasp? Failure causes in robot manipulation*, Las Vegas, USA, October 2020.
- M10. **N. Doshi** and A. Rodriguez, Hybrid iLQR for manipulation with fixed environmental contacts, In *IROS 2020 Workshop on Robotic In-Situ Servicing, Assembly, and Manufacturing*, Las Vegas, USA, October 2020.
- M9. **N. Doshi**, Planning and Control of Robotic Manipulation Primitives. In *Intelligence Community Academic Research Symposium*, National Academy of Sciences, Washington D.C., USA, September 2020.
- M8. **N. Doshi** and A. Rodriguez, Hybrid Differential dynamic Programming for planar manipulation primitives. In *IROS 2019 Workshop on Different Approaches, the Same Goal: Autonomous Object Manipulation*, Macau, China, November 2019.
- M7. **N. Doshi** and A. Rodriguez, Hybrid differential dynamic programming for planar manipulation primitives. In *IROS 2019 Workshop on Manipulation through Contacts: Bridging the Gap between Research Community and Industry*, Macau, China, November 2019.
- M6. K. Jayaram, **N. Doshi**, and R.J. Wood, Gait recovery using proprioceptive feedback in HAMR, a biologically-inspired robotic platform. In *SICP Annual Meeting 2019*, Tampa, FL, January 2019.
- M5. **N. Doshi**, K. Jayaram, B. Goldberg, Z. Manchester, R.J. Wood, and S. Kuindersma, Contact-implicit optimization of locomotion trajectories for a quadrupedal microrobot (extended abstract). In *RSS 2018 Workshop Design and Control of Small Legged Robots*, Pittsburg, PA, July 2018.
- M4. **N. Doshi**, K. Jayaram, B. Goldberg, Z. Manchester, R.J. Wood, and S. Kuindersma, Contact-implicit optimization of locomotion trajectories for a quadrupedal microrobot. *Dynamic Walking*, Pensacola, FL, May 2018.
- M3. **N. Doshi**, B. Goldberg, K. Jayaram, and R.J Wood, Task driven optimal leg trajectories in insect-scale legged microrobots. In *APS Meeting Abstracts*, New Orleans, LA, March 2017.
- M2. K. Jayaram, B. Goldberg, **N. Doshi**, and R. J. Wood, Towards rapid running at resonance using HAMR, a biologically-inspired robotic platform. *SICB Annual Meeting 2017*, New Orleans, LA, January 2017.
- M1. B. Goldberg, **N. Doshi**, O. Ozcan, and R.J. Wood, Gait studies on an insect-scale quadruped. *AMAM 2015*, Cambridge, MA, June 2015.

INTELLECTUAL PROPERTY (I)

- I1. N.C. Daffe, A. Rodriguez, **N. Doshi**, and I. Taylor. PnuGrip: an active two-phase gripper for dexterous manipulations. Provisional Application No. 63/088,113, October 6, 2020.

IN REVIEW (R) AND PREPARATION (P)

- R1 **N. Doshi***, O.T. Taylor*, and A. Rodriguez, Manipulation of unknown objects via contact configuration regulation. Submitted to *the International Conference on Robotics and Automation (ICRA)*, Philadelphia, USA, June 2022.
- R2 R. Jiang, **N. Doshi**, R. Gondhalekar, and A. Rodriguez, Shape and Motion Optimization of Rigid Planar Manipulators for Contact Trajectory Satisfaction. Submitted to *the International Conference on Robotics and Automation (ICRA)*, Philadelphia, USA, June 2022.

POPULAR PRESS (N)

- N4. Wired, TechTimes, Tech Xplore, (+15 more): Publication **J6** on inverted and vertical climbing of a quadrupedal microrobot using electroadhesion discussed in press, December 2018.
- N3. Popular Mechanics, Science Daily, My Science, Tech Xplore (+75 more): Publication **J5** on controllable water surface to underwater transition through electrowetting in a hybrid terrestrial-aquatic microrobot discussed in press, July 2018.
- N2. IEEE Spectrum, Wyss News, Tech Xplore, Digital Trends: Publication **J3** on HAMR-F, an autonomous ambulatory microrobot discussed in press, February 2018.
- N1. Science Magazine, IEEE Spectrum, The Verge, Digital Trends (+20 more): Publication **J2** on the milliDelta: A high-bandwidth, high-precision, millimeter-scale Delta robot discussed in press, January 2018.

INVITED TALKS

A Contact-Centric Approach to Robot Manipulation

- University of Pennsylvania, DAIR Lab, Philadelphia PA Oct 2021

Robotic Manipulation of Unknown Objects via Contact Configuration Regulation

- Intelligence Community Academic Research Symposium, Virtual Sep 2021

Mastering Robotic Contact: Combining Mechanisms and Algorithms

- Yale University, New Haven, CT Mar 2021
- University of North Carolina, Chapel Hill, NC Mar 2021

Planning and Control of Robotic Manipulation Primitives

- Intelligence Community Academic Research Symposium, Washington D.C. Sep 2020

Design, Control, and Planning for Legged Microrobots

- Harvard University, Self-Organizing Systems Research Group, Cambridge, MA Oct 2019
- Yale University, GRAB Lab, New Haven, CT Jul 2018
- Massachusetts Institute of Technology, MCube Lab, Cambridge, MA Jul 2018

TEACHING

Massachusetts Institute of Technology

Cambridge, MA

Teaching Assistant, 2.003 Dynamics and Control I

Fall 2020, Spring 2021

- **Undergraduate course with ~80 students.** Co-designed exams and weekly homework assignments. Co-developed and co-taught weekly recitations (3 \times /week). Held weekly office hours.

Harvard University

Cambridge, MA

Teaching Fellow, AM 202: Physical Mathematics II

Spring 2015

- **Graduate level course with ~20 students.** Co-designed and graded exams and bi-weekly homework assignments. Developed and taught bi-weekly recitations. Held weekly office hours.

TEACHING CONT.

University of Pennsylvania

Philadelphia, PA

Teaching Assistant, ENGR 105: Introduction to Scientific Computing

Fall 2010-2011

Teaching Assistant, MEAM 248: Mechanical Engineering and Applied Mechanics Lab I Spring 2011

ADVISING

Doctoral Students

Orion Taylor: Estimation and control for manipulation primitives

MIT, Sep 2019-Present

Rebecca Jiang: End-effector design optimization.

MIT, Jun 2020-Present

Masters Students

Fabian Landers: Electroadhesive pads for non-conductive substrates

Harvard Apr 2018-Apr 2019

† Sebastien de Rivaz: Inverted locomotion using electroadhesion.

Harvard, Sep 2016-May 2018

† Raphael Zufferey: Power and control autonomy for HAMR.

Harvard Sep 2014-Aug 2015

† Remo Brühwiler: Power and control autonomy for HAMR.

Harvard Sep 2014-Feb 2015

† Benedikt Sietz: Design of climbing mechanisms for HAMR.

Harvard Sep 2013-Jul 2014

Research Assistants

† Ian H. Taylor: Active two-phase grippers for dexterous manipulation.

MIT, Sep 2018-Nov 2020

† Hayley McClintock: Design of millimeter-scale devices.

Harvard, Sep 2016-Sep 2018

Undergraduate Theses

‡ Lyra Wanzer: Design of a treaded microrobot with electroadhesion.

Harvard, Sep-May 2019

Jack Zhou: Design of a bio-inspired aerial righting mechanism.

Harvard, Sep-May 2016

Undergraduate Students

† § Joshua Gruenstein: Residual model learning for microrobot control

MIT, Oct 2019-Present

Daniel Ayane: On-board circuitry for concomitant piezoelectric sensors.

Harvard, Summer 2017

Lyra Wanzer: Design of an active tail mechanism for a legged microrobot.

Harvard, Summer 2017

† Jack Zhou: Design of a passive alignment ankle for legged microrobots.

Harvard, Summer 2015

Yankang Yang: Posture on the performance of a legged microrobot.

Harvard, Summer 2015

High School Students

† Godric Li: Design of pneumatic active two-phase gripper for pivoting

MIT, Summer 2019

PROFESSIONAL SERVICE

Journal Reviewer: International Journal of Robotics Research (IJRR); Smart Materials and Structure (SMS); IEEE Robotics and Automation Letters (RA-L); IEEE Transactions on Robotics (T-RO).

Conference Reviewer: Robotics: Science and Systems (RSS), 2020; IEEE International Conference on Robotics and Automation (ICRA), 2018-2022; IEEE International Conference on Intelligent Robots and Systems (IROS), 2018-2021; and IEEE International Conference for Biomedical Robotics and Biomechatronics (BioRob), 2018.

Fellowship Reviewer: National Defense Science and Engineering Graduate Fellowship (NDSEG), 2019.

Workshop/conference Organizer: Organizer of workshop on *Advancing Artificial Intelligence and Manipulation for Robotics* at RSS 2021; Organizer of unofficial ICRAxMIT conference that highlights research from the MIT robotics community accepted at ICRA 2020; Organizer of workshop on *Uncertainty in Contact-Rich Interactions: Methods and Representations* at ICRA 2020 (Cancelled due to COVID-19).

Member: IEEE Robotics and Automation Society.

†co-authors on related refereed publications

‡winner, Dean's Design Award

§Winner, Jeremy Gerstle UROP Award for 2021