

# NEEL DOSHI

*Intelligence Community Postdoctoral Fellow*

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## EDUCATION

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<b>Harvard University</b> 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>
<b>Harvard University</b> Master of Science, Engineering Sciences	Cambridge, MA <i>Nov 2015</i>
<b>University of Pennsylvania</b> Master of Science, Robotics	Philadelphia, PA <i>May 2013</i>
<b>University of Pennsylvania</b> Bachelor of Science, <i>summa cum laude</i> , Mechanical Engineering Minors: Electrical Engineering, Mathematics	Philadelphia, PA <i>May 2012</i>

## PROFESSIONAL EXPERIENCE

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

## AWARDS AND RECOGNITIONS

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

## REFEREED JOURNAL PUBLICATIONS (J)

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- 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 materials. *Advanced Functional Materials*, In press.
- 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**

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\*contributed equally

- 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)

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- 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)

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- 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 Orelans, 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)

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- 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)

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- P2. F. Landers\*, M. Graule\*, **N. Doshi\***, K. Jayaram, and R.J. Wood, Fabrication and characterization of ultrathin interdigitated electroadhesive pads on non-conductive substrates. *In preparation*.

## POPULAR PRESS (N)

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- 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

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### Mastering Robotic Contact: Combining Mechanisms and Algorithms

- Yale University, New Haven, CT *March 2021*
- University of North Carolina, Chapel Hill, NC *March 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 *July 2018*
- Massachusetts Institute of Technology, MCube Lab, Cambridge, MA *July 2018*

## TEACHING

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### 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.

### 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

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### 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*

<sup>†</sup>Sebastien de Rivaz: Inverted locomotion using electroadhesion.

*Harvard, Sep 2016-May 2018*

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<sup>†</sup>co-authors on related refereed publications

† Raphael Zufferey: Power and control autonomy for HAMR.	<i>Harvard Sep 2014-Aug 2015</i>
† Remo Brühwiler: Power and control autonomy for HAMR.	<i>Harvard Sep 2014-Feb 2015</i>
† Benedikt Sietz: Design of climbing mechanisms for HAMR.	<i>Harvard Sep 2013-Jul 2014</i>

### Research Assistants

† Ian H. Taylor: Active two-phase grippers for dexterous manipulation.	<i>MIT, Sep 2018-Present</i>
† Hayley McClintock: Design of millimeter-scale devices.	<i>Harvard, Sep 2016-Sep 2018</i>

### Undergraduate Theses

‡ Lyra Wanzer: Design of a treaded microrobot with electroadhesion.	<i>Harvard, Sep-May 2019</i>
Jack Zhou: Design of a bio-inspired aerial righting mechanism.	<i>Harvard, Sep-May 2016</i>

### Undergraduate Students

† § Joshua Gruenstein: Residual model learning for microrobot control	<i>MIT, Oct 2019-Present</i>
Daniel Ayane: On-board circuitry for concomitant piezoelectric sensors.	<i>MIT, Summer 2017</i>
Lyra Wanzer: Design of an active tail mechanism for a legged microrobot.	<i>MIT, Summer 2017</i>
† Jack Zhou: Design of a passive alignment ankle for legged microrobots.	<i>MIT, Summer 2015</i>
Yankang Yang: Posture on the performance of a legged microrobot.	<i>MIT, Summer 2015</i>

### High School Students

† Godric Li: Design of pneumatic active two-phase gripper for pivoting	<i>MIT, Summer 2019</i>
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## 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), MDPI Sensors.

**Conference Reviewer:** Robotics: Science and Systems (RSS), 2020; IEEE International Conference on Robotics and Automation (ICRA), 2018-2021; 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.

### Organizer

- Co-organizer of workshop on *Advancing Artificial Intelligence and Manipulation for Robotics* at RSS 2021.
- Co-organizer of unofficial ICRAxMIT conference that highlights research from the MIT robotics community accepted at ICRA 2020.
- Co-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.

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‡ winner, Dean's Design Award

§ Winner, Jeremy Gerstle UROP Award for 2021