NEEL DOSHI

Intelligence Community Postdoctoral Fellow

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EDUCATION

Harvard University   Cambridge, MA
Doctor of Philoshophy, Engineering Sciences   *May 2019*
Thesis: *Model-based design, control, and planning for legged microrobots*
Advisors: Robert J. Wood & Scott Kuindersma

Harvard University   Cambridge, MA
Master of Science, Engineering Sciences   *Nov 2015*

University of Pennsylvania   Philadelphia, PA
Master of Science, Robotics   *May 2013*

University of Pennsylvania   Philadelphia, PA
Bachelor of Science, *summa cum laude*, Mechanical Engineering *May 2012*
Minors: Electrical Engineering, Mathematics

PROFESSIONAL EXPERIENCE

Massachusetts Institute of Technology   Cambridge, MA
IC Postdoctoral Fellow, The MCube Lab   *April 2019-Present*

- 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   Cambridge, MA
Doctoral Student, Harvard Microrobotics Laboratory   *Sept 2013-March 2019*

- 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   Philadelphia, PA
Research Assistant, ModLab   *Mar 2012-July 2013*

- 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   Greenbelt, MD
Robotics Intern, NASA-GSFC   *Summer 2011*

- 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   Philadelphia, PA
Research Assistant, ModLab   *Summer 2010*

- 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

Intelligence Community Postdoctoral Research Fellowship	*Oct 2019*
2nd Prize, IBM Research: ISS Meets AI	*Sept 2019*
Finalist, Best Conference Paper Award (ICRA)	*June 2018*
Finalist, Best Conference Paper Award (IROS)	*Sept 2017*
Certificate of Distinction in Teaching	*May 2015*
Best Automation Paper (ICRA)	*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)

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**

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**

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.

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*contributed equally

REFEREED CONFERENCE PUBLICATIONS (C)

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

POSTERS, WORKSHOPS, AND ABSTRACTS (M)

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)

I1. N.C. Dafle, 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)

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

P1. 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. *In preparation.*

R1. J. Gruenstein, T. Chen, **N. Doshi**, and Pulkit Agrawal. Residual model learning for microrobot control. In review: *The International Conference on Robotics and Automation (ICRA)*, 2021.

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

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

Massachusetts Institute of Technology   Cambridge, MA
Teaching Assistant, 2.003 Dynamics and Control I   *Fall 2020*
- **Undergraduate course with ~80 students**. Co-designed exams and weekly homework assignments. Co-developed and co-taught weekly recitations (3 ×/week) with Professor Vandiver. 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

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-Present*
† 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*

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‡winner, Dean's Design Award

Undergraduate Students

† Joshua Gruenstein: Residual model learning for microrobot control   *MIT, Oct 2019-Present*
Daniel Ayane: On-board circuitry for concomitant piezoelectric sensors.   *MIT, Summer 2017*
Lyra Wanzer: Design of an active tail mechanism for a legged microrobot.   *MIT, Summer 2017*
† Jack Zhou: Design of a passive alignment ankle for legged microrobots.   *MIT, Summer 2015*
Yankang Yang: Posture on the performance of a legged microrobot.   *MIT, 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), 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), *2018-2020*; 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 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.

REFERENCES

Alberto Rodriguez
Associate Professor without tenure
Department of Mechanical Engineering
Massachusetts Institute of Technology
albertor@mit.edu

Robert J. Wood
Charles River Professor
John A. Paulson School of Engineering & Applied Sciences
Harvard University
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Scott Kuindersma
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Zachary Manchester
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John Kim Vandiver
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Forbes Director of the Edgerton Center
Department of Mechanical and Ocean Engineering
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kimv@mit.edu