

Devin J. Balkcom

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RESEARCH INTERESTS	Efficient designs and algorithms for robot locomotion and manipulation. How can robotics problems be solved in simple, effective ways?	
EDUCATION	Carnegie Mellon University , Robotics Ph.D. 2004. Advisor Matthew Mason. Johns Hopkins University , B.A. 1998	
APPOINTMENTS	Department Chair , Dartmouth Computer Science Professor , Dartmouth College Associate Professor , Dartmouth College Faculty Co-director of Academic Computing , Dartmouth College Assistant Professor , Dartmouth College	2020 – present 2020 – present 2010-2020 2013 – 2016 2004 – 2010
AWARDS	Dartmouth McLane family fellowship, 2010-2011. John M. Manley Huntington Award for Newly Tenured Faculty, 2010. NSF CAREER award, 2006. Department of Energy Computational Science Graduate Fellowship, 2000	
FUNDING	NSF MRI: Acq. of marine multirobot systems for underwater monitoring and construction co-PI. Total funding \$400k, with Quattrini Li, Casana, Zhou, Zhu. RII Track-2 FEC: Computational Methods and Autonomous Robotics Systems for Modeling and Predicting Harmful Cyanobacterial Blooms Total funding \$2.9M, renewable to \$5.9M, P.I. Quattrini Li (senior personnel; single investigator per institution) NSF Cyberlearning: Teaching Human Motion at Population Scale PI. Total funding \$750k, with Kraemer, Zhou, Wang. NSF RI: Computational joinery PI. Total funding \$500k, with Whiting, Wang. MBR Space Settlement Challenge \$16,000. Adobe Research gift \$10,000. Neukom Comp-X grant: Computational design of deployable structures \$15,000. With Emily Whiting. NSF EAGER: Computing compact roadmaps for motion planning P.I. \$150k. NSF RI: Practical techniques for robotic manipulation of string and wire P.I. \$482k. Neukom Comp-X grant: Efficient representations for robot motion planning \$20k. With Amit Chakrabarti.	2019 – 2022 2019 – 2023 2018 – 2021 2018 – 2020 2018 2017 2016 2014 – 2016 2012 – 2016 2012

NSF Infrastructure grant: Digital Imaging Laboratory at Dartmouth	2007 – 2010
\$480k. With Hany Farid, Fabio Pellacini, Lorie Loeb.	
NSF CAREER award	2006 – 2011
\$400k.	
Department of Justice (ISTS): Mobility assessment for emergency response robots	2006 – 2008
\$250k. Co-PI with Laura Ray.	
Department of Justice Byrne Grant: automated assistance for disaster response	2005 – 2007
\$181k. Co-PI with Laura Ray.	
Department of Energy Computational Science Graduate Fellowship	2000 – 2004
Full graduate student support; approximately \$220k.	

PH.D. STUDENTS	Julien Blanchet	September 2019 – present
	Luyang Zhao	September 2018 – present
	Sam Lensgraf (coadvised by A. Quattrini Li)	September 2018 – present
	Qijia Shao (coadvised by Xia Zhou)	November 2018 – present
	Amy Sniffen (coadvised by Xia Zhou)	November 2018 – present
	Yinan Zhang	Ph.D. June 2019
	Yu-Han Lyu	Ph.D. June 2016
	Weifu Wang	Ph.D. June 2016
	Andrei Furtuna	Ph.D. June 2011
	Paritosh Kavathekar	Ph.D. June 2011
Matthew Bell	Ph.D. February 2010	

M.S. STUDENTS	Yijia Wu	current
	Evan Honnold	July 2019
	Fahad Hamid	July 2019
	Chang Jo Kim	September 2013
	Zhong Li	June 2013
	Wenyu Lu	August 2011
	Govind Krishnan	September 2009
	Wei Zhang (coadvised by Paul Thompson)	June 2007
	Anne Loomis	June 2006

COURSES TAUGHT	Tuck FWP: Fundamentals of Web Programming	2016 – 2020
	With Hany Farid, designed, developed, and taught a new course for Tuck students interested in the intersection of technology and business. This hands-on-course covers web development in Javascript, HTML, CSS, with a particular emphasis on business applications.	
	Tuck DSA: Data structures and analytics	2017
With Hany Farid, designed, developed, and taught a new course for Tuck students interested in the intersection of technology and business. This hands-on-course follows the prior FWP course, and covers managing data in databases, representing data for computation in data structures, and data analysis using techniques from computer science and machine learning, with a particular emphasis on business applications.		
	CS 1: Introduction to Programming and Computation	2005 – present
I designed and developed a new introductory undergraduate course, intended for both majors and non-majors. The course is programming intensive, and teaches fundamentals of Python programming, introductory object-oriented design, and topics from algorithms and data structures,		

including linked lists, trees, graphs, breadth-first search, and finite automata.

CS 81: Principles of Robot Design and Programming 2006 – present

This advanced undergraduate course that I developed covers robot design and programming. There are two primary foci: a sequence of labs, and a rigorous introduction to mathematical techniques for analysis. The labs involve four mobile robots that the students program to autonomously explore a maze, and a real industrial robot arm that the student program for manipulation and assembly tasks. The mathematical analysis side covers kinematics, dynamics, the basics of modern control, and analysis of the stability of robot grasping.

CS 76: Artificial Intelligence various years, 2005 – present

This senior undergraduate course introduces basic applications and techniques in the field of Artificial Intelligence. Topics include knowledge representation, A* and iterative deepening search, scheduling, logic and theorem proving, competitive and cooperative games, optimization, probabilistic inference, with applications to robotics, natural language processing, and computer game development.

CS 50: Software Design and Implementation 2011, 2013

This course is an intermediate course in software development and design. Students who have completed the first two introductory courses build a team project in this course, using C and Unix development tools. In the version of the course I developed and taught, students built a multi-player, networked, threaded implementation of a music-teaching game along the lines of the well-known commercial *Guitar Hero* game.

CS 89: Robotics seminar 2005 – 2018

This undergraduate/graduate course presents basic techniques for modeling, simulation, planning, and control of robotic systems. Topics covered include configuration space, kinematics of open and closed chains, representations of rotations in 2D and 3D, homogeneous coordinates, constrained dynamics, the dynamics of friction and contact. Lab work includes programming an industrial robot arm.

CS 98: Senior design project 2012, 2013, 2014, 2015

This course represents a culminating experience for graduating senior undergraduates. As part of a team, students design, develop, test, and release a piece of software.

CS 69: Design projects course 2013

This course is a team-project course along the lines of CS 98, but targeted at first-, second-, and third-year students.

UNDERGRADUATE RESEARCH ADVISING I have supervised more than 80 undergraduates on individual research projects, through the Dartmouth Women in Science Project, Presidential fellowship program, E.E. Just minority research program, and for senior theses.

PROFESSIONAL COMMITTEES *IEEE Robotics and Automation Letters* Associate Editor 2015 – present

NSF proposal review panels 2008, 2009, 2012, 2013, 2014, 2015

Workshop on the Algorithmic Foundations of Robotics (WAFR) program committee 2010, 2012, 2014, 2016

IEEE/RSJ International Conference on Intelligent Robots and Systems associate editor. 2005, 2006, 2007, 2011, 2012, 2013, 2014

IEEE International Conference on Robotics and Automation associate editor. 2011, 2012, 2013, 2014

Robotics: Science and Systems program committee. 2005, 2006, 2007, 2008, 2010, 2012

Reviewer for *The International Journal of Robotics Research*, the *IEEE Transactions on Robotics and Automation*, and other international journals. Judge for FIRST lego robotics competition, and for ASME National Student Mechanical Design Competition. Program committee member for *AAAI* and *Intelligent Autonomous Systems*. Area and publicity chair for *Robotics: Science and Systems* (2009).

UNDERGRADUATES ADVISED SINCE 2012 Numbers in parenthesis indicate number of terms supervised on research or development project.

1. Xingran Zhuang (2) Senior thesis
2. Shoshana Geller (1) Lab RA
3. Gregory Hunter (1) Lab RA
4. Andrea Jenkins (1) Lab RA
5. Xingran.Zhuang (1) Lab RA
6. Christina Lu (1) Presidential scholar
7. Karim Itani (1) Lab RA
8. Jennifer Jain (2) Lab RA
9. David Mena (1) Lab RA
10. Geoffry Wang (4) Lab RA
11. Lisa Oh (5) Senior thesis
12. Josiah Putman (4) Neukom Fellow
13. Madeleine Genereux (1) Lab RA
14. David Perez Gonzalez (1) E.E. Just Fellow
15. Janvi Kalra (2) Lab RA
16. Eitan Vilker (1) Lab RA
17. Braden Pellowski (1) Senior thesis
18. Cara Van Uden (1) Lab RA
19. Magdalene Pizzo (1) Lab RA
20. Robert Livaudis (1) Lab RA
21. Evan Honnold (4) Senior thesis
22. Galen Brown (3) Senior thesis
23. Anthony Addo (2) Senior thesis
24. Yusuf Olokoba (6) E.E. Just Fellow
25. Ping-Jung Liu (1) Lab RA
26. Zachary Johnson (2) Lab RA
27. Yichen Ke (2) Presidential scholar
28. Hang Qi (4) Presidential scholar
29. Pritika Vg (2) Senior thesis
30. Michael Li (5) Senior thesis, Neukom scholar
31. Kaya Thomas (2) Independent study for credit
32. Nan Hu (3) Presidential scholar
33. Ella Ryan (3) Presidential scholar
34. Justin Chan (3) Presidential scholar
35. Ajay Kannan (3) Senior thesis
36. Richard Addo (1) Course credit
37. Hanna Kim (2016, 1) Course credit
38. Yining Chen (4) Presidential scholar
39. Justin Murray (3) Senior thesis
40. Jonathan Guinter (3) Senior thesis
41. Delos Chang (2) Senior thesis
42. Will Jackson (2) Senior thesis
43. Jordan Kunzika (8) Sophomore Science, lab RA
44. George Boateng (6) Sophomore Science, lab RA
45. Charles Pastuzenski (2) Presidential scholar
46. Kelsey Harris (3) Senior thesis
47. E McNeil (3) Senior thesis
48. Divya Gunasekaran (3) Senior thesis
49. Parker Phinney (3) Senior thesis
50. Ambrose Granizo-Mackenzie (4) Hanover high, lab RA
51. Stephen Malina (2) lab RA
52. Dan Carter (2) lab RA
53. Callen Votzke (10), lab RA
54. Xander Eisensten (1), lab RA
55. Peter Stein (2), reading course
56. Kevin NiParko (2), reading course
57. David Rogg (2), reading course
58. Carla Galarza (1) Summer robotics camp instructor/ developer
59. Sucharita Jayanti (1) Summer robotics camp instructor/ developer
60. Max Diebel (1) Summer robotics camp instructor/ developer
61. Daniel Mott (2) Lab RA
62. Jennifer Lure (2) Lab RA

JOURNAL ARTICLES

- [1] Ruibo Liu, Qijia Shao, Siqi Wang, Christina Ru, Devin Balkcom, and Xia Zhou. “Reconstructing Human Joint Motion with Computational Fabrics”. In: *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 3.1 (2019), 19:1–19:26.
- [2] Yinan Zhang, Emily Whiting, and Devin Balkcom. “Assembling and disassembling planar structures with divisible and atomic components”. In: *IEEE Transactions on Automation Science and Engineering* 15.3 (July 2018), pp. 945–954.
- [3] Weifu Wang and Devin Balkcom. “Knot grasping, folding, and re-grasping”. In: *International Journal of Robotics Research* 37.2-3 (Feb. 2018), pp. 378–399.
- [4] Yu-Han Lyu and Devin Balkcom. “Optimal trajectories for planar rigid bodies with switching costs”. In: *International Journal of Robotics Research* 35.5 (2016), pp. 454–475.
- [5] Yu-Han Lyu, Yining Chen, and Devin Balkcom. “k-survivability: diversity and survival of expendable robots”. In: *Robotics and Automation Letters* 1.2 (2016). Also published as ICRA article by the same name., pp. 1164–1171.
- [6] Weifu Wang and Devin Balkcom. “Towards arranging and tightening knots and unknots with fixtures”. In: *IEEE Transactions on Automation Science and Engineering* 12.4 (2015), pp. 1318–1331.
- [7] Weifu Wang, Devin Balkcom, and Amit Chakrabarti. “A fast online spanner for roadmap construction”. In: *International Journal of Robotics Research* 34.11 (2015), pp. 1418–1432.
- [8] Matthew P. Bell, Weifu Wang, Jordan Kunzika, and Devin Balkcom. “Knot-tying with four-piece fixtures”. In: *International Journal of Robotics Research* 33.11 (2014), pp. 1481–1489.
- [9] Paritosh A. Kavathekar, Bruce A. Craig, Alan M. Friedman, Chris Bailey-Kellogg, and Devin Balkcom. “Characterizing the space of interatomic distance distribution functions consistent with solution scattering data”. In: *Journal of Bioinformatics and Computational Biology* 8.2 (2010), pp. 315–335.
- [10] Matthew P. Bell and Devin Balkcom. “Grasping non-stretchable cloth polygons”. In: *International Journal of Robotics Research* 29.6 (2010), pp. 775–784.
- [11] Andrei A. Furtuna and Devin Balkcom. “Generalizing Dubins curves: minimum-time sequences of body-fixed rotations and translations in the plane”. In: *International Journal of Robotics Research* 29.6 (2010), pp. 703–726.
- [12] Hamid Reza Chitsaz, Steven M. LaValle, Devin Balkcom, and Matthew T. Mason. “Minimum wheel-rotation paths for differential-drive mobile robots”. In: *International Journal of Robotics Research* 28.1 (2009), pp. 66–80.
- [13] Devin Balkcom and Matthew T. Mason. “Robotic origami folding”. In: *International Journal of Robotics Research* 27.5 (2008), pp. 613–627.
- [14] Devin Balkcom, Paritosh A. Kavathekar, and Matthew T. Mason. “Time-optimal trajectories for an omni-directional vehicle”. In: *International Journal of Robotics Research* 25.10 (2006), pp. 985–999.
- [15] Devin Balkcom and Jeffrey C. Trinkle. “Computing wrench cones for planar rigid body contact tasks”. In: *International Journal of Robotics Research* 21.12 (2002), pp. 1053–1066.
- [16] Devin Balkcom and Matthew T. Mason. “Time optimal trajectories for bounded velocity differential drive vehicles”. In: *International Journal of Robotics Research* 21.3 (2002), pp. 199–218.

CONFERENCE PAPERS

- [17] Josiah Putman, Lisa Oh, Luyang Zhao, Evan Honnold, Galen Brown, Weifu Wang, and Devin J. Balkcom. “LLDM: Locally linear distance maps for robot motion planning: Extended Abstract”. In: *2019 International Symposium on Multi-Robot and Multi-Agent Systems, MRS*. 2019.
- [18] Yinan Zhang and Devin Balkcom. “Interlocking block assembly”. In: *Algorithmic Foundation of Robotics (WAFR)*. Dec. 2018.
- [19] Weifu Wang and Devin Balkcom. “Time-optimal motion of spatial Dubins systems”. In: *Algorithmic Foundation of Robotics (WAFR)*. Dec. 2018.
- [20] Devin Balkcom, Andrei Furtuna, and Weifu Wang. “The Dubins car and other arm-like mobile robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. May 2018.

- [21] Yinan Zhang, Xiaolei Chen, Hang Qi, and Devin Balkcom. “Rearranging agents in a small space using global controls”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2017.
- [22] Paritosh Kavathekar and Devin Balkcom. “A tactile shirt for teaching human motion tasks”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2017.
- [23] Yinan Zhang, Emily Whiting, and Devin Balkcom. “Assembling and disassembling planar structures with divisible and atomic components”. In: *Algorithmic Foundations of Robotics (WAFR)*. 2016.
- [24] Weifu Wang and Devin Balkcom. “Re-configuring knots to simplify manipulation”. In: *Algorithmic Foundations of Robotics (WAFR)*. 2016.
- [25] Yinan Zhang and Devin Balkcom. “Interlocking structure assembly with voxels”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2016.
- [26] Weifu Wang and Devin Balkcom. “Grasping and folding knots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2016.
- [27] Weifu Wang and Devin Balkcom. “Towards tying knots precisely”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2016.
- [28] Yu-Han Lyu, Yining Chen, and Devin Balkcom. “k-survivability: diversity and survival of expendable robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. Also published as RAL journal article by the same name. 2016.
- [29] Devin Balkcom, Ajay Kannan, Yu-Han Lyu, Weifu Wang, and Yinan Zhang. “Metric cells: towards complete search for optimal trajectories”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2015.
- [30] Weifu Wang, Dmitry Berenson, and Devin Balkcom. “An online method for tight-tolerance insertion tasks for string and rope”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2015.
- [31] Yu-Han Lyu, Andrei A. Furtuna, Weifu Wang, and Devin Balkcom. “The bench mover’s problem: minimum-time trajectories, with cost for switching between controls”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2014, pp. 106–112.
- [32] Weifu Wang, Matthew Bell, and Devin Balkcom. “Towards arranging and tightening knots and unknots with fixtures”. In: *Algorithmic Foundations of Robotics (WAFR)*. 2014.
- [33] Yu-Han Lyu and Devin Balkcom. “Optimal trajectories for planar rigid bodies with switching costs”. In: *Algorithmic Foundations of Robotics (WAFR)*. 2014.
- [34] Weifu Wang, Devin Balkcom, and Amit Chakrabarti. “A fast streaming spanner algorithm for incrementally constructing sparse roadmaps”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2013, pp. 1257–1263.
- [35] Zhong Li, Devin Balkcom, and Aaron M. Dollar. “Rigid 2D space-filling folds of unbroken linear chains”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2013, pp. 551–557.
- [36] Andrei A. Furtuna, Weifu Wang, Yu-Han Lyu, and Devin Balkcom. “Structure and geometry of minimum-time trajectories for planar rigid bodies”. In: *Allerton Conference on Communication, Control, and Computing*. 2013, pp. 1584–1591.
- [37] Weifu Wang and Devin Balkcom. “Sampling extremal trajectories for planar rigid bodies”. In: *Algorithmic Foundations of Robotics (WAFR)*. 2012, pp. 331–347.
- [38] Weifu Wang and Devin Balkcom. “Analytical time-optimal trajectories for an omni-directional vehicle”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2012, pp. 4519–4524.
- [39] Andrei A. Furtuna, Wenyu Lu, Weifu Wang, and Devin Balkcom. “Minimum-time trajectories for kinematic mobile robots and other planar rigid bodies with finite control sets”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2011, pp. 4321–4328.
- [40] Andrei A. Furtuna, Devin Balkcom, Hamid Reza Chitsaz, and Paritosh A. Kavathekar. “Generalizing the Dubins and Reeds-Shepp cars: fastest paths for bounded-velocity mobile robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2008, pp. 2533–2539.
- [41] Matthew P. Bell and Devin Balkcom. “Knot tying with single piece fixtures”. In: *IEEE International Conference on Robotics and Automation, (ICRA)*. 2008, pp. 379–384.

- [42] Laura Ray, James Joslin, John Murphy, Jon Barlow, Devin Brande, and Devin Balkcom. “Dynamic mobile robots for emergency surveillance and situational awareness”. In: *IEEE International Workshop on Safety, Security, and Rescue Robotics*. 2006.
- [43] Devin Balkcom, Erik Demaine, Martin Demaine, John Ochsendorf, and Zhong You. “Folding paper shopping bags”. In: *International Meeting of Origami Science, Math, and Education (OSME)*. 2006, pp. 315–334.
- [44] Devin Balkcom, Paritosh A. Kavathekar, and Matthew T. Mason. “The minimum-time trajectories for an omni-directional vehicle”. In: *Algorithmic Foundation of Robotics (WAFR)*. Superseded by IJRR article. 2006, pp. 343–358.
- [45] Anne Loomis and Devin Balkcom. “Computation reuse for rigid-body dynamics”. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2006, pp. 4181–4186.
- [46] Hamid Reza Chitsaz, Steven M. LaValle, Devin Balkcom, and Matthew T. Mason. “Minimum wheel-rotation Paths for differential-drive mobile robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. Superseded by IJRR paper. 2006, pp. 1616–1623.
- [47] Devin Balkcom and Matthew T. Mason. “Introducing robotic origami folding”. In: *IEEE International Conference on Robotics and Automation*. 2004, pp. 3245–3250.
- [48] Devin Balkcom and Matthew T. Mason. “Extremal trajectories for bounded velocity mobile robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2002, pp. 1747–1752.
- [49] Devin Balkcom, E. J. Gottlieb, and Jeffrey C. Trinkle. “A sensorless insertion strategy for rigid planar parts”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. Superseded by IJRR article. 2002, pp. 882–887.
- [50] Devin Balkcom, Jeffrey C. Trinkle, and E. J. Gottlieb. “Computing wrench cones for planar contact tasks”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2002, pp. 869–875.
- [51] Devin Balkcom and Matthew T. Mason. “Progress in desktop robotics”. In: *The Eleventh Yale Workshop on Adaptive and Learning Systems*. 2001.
- [52] Devin Balkcom and Matthew T. Mason. “Time optimal trajectories for bounded velocity differential drive robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2000, pp. 2499–2504.
- [53] Devin Balkcom and Matthew T. Mason. “Extremal trajectories for bounded velocity differential drive robots”. In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2000, pp. 2479–2484.

ONLINE TEXTS

- [54] Yinan Zhang, Devin J. Balkcom, and Haoxiang Li. *Towards Physically Safe Reinforcement Learning under Supervision*. arXiv. 2019. arXiv: 1901.06576.
- [55] Samuel Lensgraf, Karim Itani, Yinan Zhang, Zezhou Sun, Yijia Wu, Alberto Quattrini Li, Bo Zhu, Emily Whiting, Weifu Wang, and Devin Balkcom. *PuzzleFlex: kinematic motion of chains with loose joints*. arXiv. 2019. arXiv: 1906.08708 [cs.RO].
- [56] Devin Balkcom. *Project Python: an interactive introduction to Computer Science*. On-line at projectpython.net. 170 pages. 2011.
- [57] Devin Balkcom and Tom Cormen. *Algorithms Tutorials*. On-line at Khan Academy. 60 pages. 2015.
- [58] Devin Balkcom. *Java for coders*. On-line at www.educative.io. 22 pages. 2017.

PH.D. THESES SUPERVISED

- [59] Matthew P. Bell. “Flexible Object Manipulation”. PhD thesis. Hanover, NH: Dartmouth Computer Science, 2010.
- [60] Paritosh A. Kavathekar. “Assisting Human Motion-Tasks with Minimal, Real-time Feedback”. PhD thesis. Hanover, NH: Dartmouth Computer Science, 2011.
- [61] Andrei A. Furtuna. “Minimum time kinematic trajectories for self-propelled rigid bodies in the unobstructed plane”. PhD thesis. Hanover, NH: Dartmouth Computer Science, 2011.
- [62] Yu-Han Lyu. “Implications of Motion Planning: Optimality and k-survivability”. PhD thesis. Hanover, NH: Dartmouth Computer Science, 2016.

- [63] Weifu Wang. "Constraint-based robot knot tying". PhD thesis. Hanover, NH: Dartmouth Computer Science, 2016.
- [64] Yinan Zhang. "Interlocking structure design and assembly ". PhD thesis. Hanover, NH: Dartmouth Computer Science, 2019.