

# SUBHRAJIT BHATTACHARYA

## Assistant Professor

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### BIOGRAPHICAL INFORMATION

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#### Educational History

*M.S. and Ph.D., Mechanical Engineering and Applied Mechanics:* (January 2012)

University of Pennsylvania, USA.

Ph.D. dissertation title: *Topological and Geometric Techniques in Graph Search-Based Robot Planning.*

Ph.D. supervisors: Prof. Vijay Kumar and Prof. Maxim Likhachev.

*B.Tech., Mechanical Engineering:* (June 2006)

Indian Institute of Technology, Kharagpur, India.

#### Employment History and Professional Experience

*Assistant Professor:* (August 15, 2016 – present)

Department of Mechanical Engineering and Mechanics, Lehigh University, USA.

*Postdoctoral Researcher:* (February 2012 – August 15, 2016)

Department of Mathematics, University of Pennsylvania, USA.

Supervisors: Prof. Vijay Kumar and Prof. Robert Ghrist.

### PUBLICATIONS

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#### Refereed Journal Publications

1. Xiaolong Wang, Alp Sahin and Subhrajit Bhattacharya, “*Coordination-free Multi-robot Path Planning for Congestion Reduction Using Topological Reasoning*”, Journal of Intelligent and Robotic Systems (JINT), Springer Nature, 2023. DOI:10.1007/s10846-023-01878-3.
2. Subhrajit Bhattacharya, “*On some bounds on the perturbation of invariant subspaces of normal matrices with application to a graph connection problem*”, Journal of Inequalities and Applications, 1:75, Springer, 2022.
3. Xiaolong Wang, Matt Bilsky and Subhrajit Bhattacharya, “*Search-based Configuration Planning and Motion Control Algorithms for a Snake-like Robot Performing Load-intensive Operations*”, Autonomous Robots (AURO), 45:1047-1076, Springer, 2021.
4. Leiming Zhang, Amanda Prorok and Subhrajit Bhattacharya, “*Pursuer Assignment and Control Strategies in Multi-Agent Pursuit-Evasion Under Uncertainties*”, Frontiers in Robotics and AI, 8:262, 2021. DOI:10.3389/frobt.2021.691637.
5. Leiming Zhang, Brian M. Sadler, Rick S. Blum and Subhrajit Bhattacharya, “*Inter-cluster Transmission Control Using Graph Modal Barriers*”, IEEE Transactions on Signal and Information Processing over Networks, 7:275-293, April, 2021. DOI:10.1109/TSIPN.2021.3071219.
6. Subhrajit Bhattacharya, “*Towards Optimal Path Computation in a Simplicial Complex*”, International Journal of Robotics Research (IJRR), 38(8):981-1009, June, 2019. DOI: 10.1177/0278364919855422.
7. Bo Tian and Subhrajit Bhattacharya, “*Modelling and Control of a Spatial Dynamic Cable*”, Acta Mechanica Sinica, 35:866-878, Springer, Apr, 2019.
8. Subhrajit Bhattacharya and Robert Ghrist, “*Path Homotopy Invariants and their Application to Optimal Trajectory Planning*”, Annals of Mathematics and Artificial Intelligence, 84(3-4):139-160, Springer International Publishing, December, 2018.
9. Xiaolong Wang and Subhrajit Bhattacharya, “*A Topological Approach to Workspace and Motion Planning for a Cable-controlled Robot in Cluttered Environments*”, IEEE Robotics and Automation Letters (RA-L), 3(3):2600-2607, July 2018. DOI: 10.1109/LRA.2018.2817684.
10. Dhanushka Kularatne, Subhrajit Bhattacharya and M Ani Hsieh, “*Going with the flow: a graph based approach to optimal path planning in general flows*”, Autonomous Robots (AURO), 42(7):1369-1387, Springer, Oct, 2018. DOI: 10.1007/s10514-018-9741-6

11. Monroe Kennedy III, Dinesh Thakur, M. Ani Hsieh, Subhrajit Bhattacharya and Vijay Kumar, “*Optimal Paths for Polygonal Robots in SE(2)*”, ASME Journal of Mechanisms and Robotics, 10(2):021005-021005-8, Feb, 2018. DOI:10.1115/1.4038980.
12. Dhanushka Kularatne, Subhrajit Bhattacharya and M. Ani Hsieh, “*Optimal Path Planning in Time-Varying Flows using Adaptive Discretization*”, IEEE Robotics and Automation Letters (RA-L), 3(1):458-465, 2017.
13. Sikang Liu, Michael Watterson, Kartik Mohta, Ke Sun, Subhrajit Bhattacharya, Camillo Jose Taylor and Vijay Kumar, “*Planning Dynamically Feasible Trajectories using Safe Flight Corridors in 3-D Complex Environments*”, IEEE Robotics and Automation Letters (RA-L), 2(3):1688-1695, January, 2017.
14. Rattanachai Ramaithitima, Michael Whitzer, Subhrajit Bhattacharya and Vijay Kumar, “*Automated Creation of Topological Maps in Unknown Environments Using a Swarm of Resource-Constrained Robots*”, IEEE Robotics and Automation Letters (RA-L), 1(2):746–753, January, 2016. DOI: 10.1109/LRA.2016.2523600.
15. Subhrajit Bhattacharya, Robert Ghrist and Vijay Kumar, “*Persistent Homology for Path Planning in Uncertain Environments*”, IEEE Transactions on Robotics (T-RO), 31(3):578-590, April, 2015. DOI: 10.1109/ TRO.2015. 2412051.
16. Subhrajit Bhattacharya, Soonkyum Kim, Hordur Heidarsson, Gaurav Sukhatme and Vijay Kumar, “*A Topological Approach to using cables to separate and manipulate sets of objects*”, International Journal of Robotics Research (IJRR), 34(6):799–815, April, 2015. DOI: 10.1177/0278364914562236.
17. Subhrajit Bhattacharya and Mihail Pivtoraiko, “*A Classification of Configuration Spaces of Planar Robot Arms for a Continuous Inverse Kinematics Problem*”, Acta Applicandae Mathematicae, 139(1):133-166, October 2015, Springer Netherlands. DOI: 10.1007/s10440-014-9973-1.
18. Subhrajit Bhattacharya, Robert Ghrist and Vijay Kumar, “*Multi-robot Coverage and Exploration on Riemannian Manifolds with Boundary*”. International Journal of Robotics Research (IJRR), 33(1):113-137, October 2013, SAGE Publishers. DOI: 10.1177/0278364913507324.
19. Subhrajit Bhattacharya, David Lipsky, Robert Ghrist and Vijay Kumar, “*Invariants for Homology Classes with Application to Optimal Search and Planning Problem in Robotics*”, Annals of Mathematics and Artificial Intelligence (AMAI), 67(3-4):251-281, March 2013, Springer. DOI: 10.1007/s10472-013-9357-7.
20. Subhrajit Bhattacharya, Maxim Likhachev and Vijay Kumar, “*Topological Constraints in Search-based Robot Path Planning*”, Autonomous Robots (AURO), 33(3):273-290, October 2012, Springer Netherlands. DOI: 10.1007/ s10514-012-9304-1.
21. Subhrajit Bhattacharya, Siddharth Talapatra, “*Robot Motion Planning Using Neural Networks: A Modified Theory*”, International Journal of Lateral Computing, Vol.2, No.1, December 2005, ISSN 0973-208X, 9-13.

#### Peer-reviewed Conference Publications

1. Diego S. D’Antonio, Subhrajit Bhattacharya and David Saldana, “*Forming and Controlling Hitches in Midair Using Aerial Robots*”. In 2023 International Conference on Robotics and Automation (ICRA), May 29-June 2, 2023.
2. Wenying Wu, Subhrajit Bhattacharya and Amanda Prorok, “*Multi-Robot Path Deconfliction through Prioritization by Path Prospects*”. In 2020 International Conference on Robotics and Automation (ICRA), May-Aug, 2020.
3. Leiming Zhang, Amanda Prorok and Subhrajit Bhattacharya, “*Multi-Agent Pursuit-Evasion under Uncertainties with Redundant Robot Assignments*”, In IEEE International Symposium on Multi-Robot and Multi-Agent Systems. 22-23, August, 2019. [Extended abstract published.]
4. Xiaolong Wang and Subhrajit Bhattacharya, “*A Topological Approach to Workspace and Motion Planning for a Cable-Controlled Robot in Cluttered Environments*”, In International Conference on Intelligent Robots (IROS). 1-5, October, 2018.
5. Rattanachai Ramaithitima and Subhrajit Bhattacharya, “*Landmark-based Exploration with Swarm of Resource Constrained Robots*”, In International Conference on Robotics and Automation (ICRA), 2018.
6. Monroe Kennedy III, Dinesh Thakur, M. Ani Hsieh, Subhrajit Bhattacharya and Vijay Kumar, “*Optimal Paths for Polygonal Robots in SE(2)*”, In Proceedings of the ASME 2017 International Design Engineering Technical Conferences (IDETC). Cleveland, OH, USA, Aug, 2017.

7. Xin Li, Mooi Chuah and Subhrajit Bhattacharya, “*UAV Assisted Smart Parking Solution*”, In 2017 International Conference on Unmanned Aircraft Systems (ICUAS). Miami, FL, USA, June, 2017.
8. Luis Guerrero-Bonilla, Kartik Mohta, Subhrajit Bhattacharya and Vijay Kumar, “*Flight Trajectory Tracking and Recovery in Presence of Large Disturbances*”, In 2017 International Conference on Unmanned Aircraft Systems (ICUAS). Miami, FL, USA, June, 2017.
9. Sikang Liu, Michael Watterson, Kartik Mohta, Ke Sun, Subhrajit Bhattacharya, Camillo Jose Taylor and Vijay Kumar, “*Planning Dynamically Feasible Trajectories using Safe Flight Corridors in 3-D Complex Environments*”, IEEE International Conference on Robotics and Automation (ICRA), May 29 - June 3, Singapore, 2017.
10. Sarah Costrell, Subhrajit Bhattacharya and Robert Ghrist, “*Reconstruction of Euclidean Embeddings in Dense Networks*”, In Proceedings of the IEEE Global Conference on Signal and Information Processing (GlobalSIP). Washington, D.C., USA, IEEE Signal Processing Society, 7-9 Dec, 2016.
11. Rattanachai Ramaithitima, Siddharth Srivastava, Subhrajit Bhattacharya, Alberto Speranzon and Vijay Kumar, “*Hierarchical Strategy Synthesis for Pursuit-Evasion Problems*”, In Proceedings of the European Conference on Artificial Intelligence (ECAI). August, 2016.
12. Michael Whitzer, James Keller, Subhrajit Bhattacharya, Vijay Kumar, Trevor Sands, Lee Ritholtz, Adrian Pope and Dean Dickmann, “*In-Flight Formation Control for a Team of Fixed-Wing Aerial Vehicles*”, In Proceedings of The 2016 International Conference on Unmanned Aircraft Systems (ICUAS), June 2016.
13. Dhanushka Kularatne, Subhrajit Bhattacharya and M. Ani Hsieh, “*Time and Energy Optimal Path Planning in General Flows*”, In Proceedings of the Robotics: Science and System (RSS), June 2016.
14. Rattanachai Ramaithitima, Michael Whitzer, Subhrajit Bhattacharya and Vijay Kumar, “*Automated Creation of Topological Maps in Unknown Environments Using a Swarm of Resource-Constrained Robots*”, In Proceedings of IEEE International Conference on Robotics and Automation (ICRA), May 2016.
15. Subhrajit Bhattacharya and Robert Ghrist, “*Path Homotopy Invariants and their Application to Optimal Trajectory Planning*”, In Proceedings of IMA Conference on Mathematics of Robotics (IMAMR), St Anne’s College, University of Oxford, September 9-11, 2015.
16. Rattanachai Ramaithitima, Mickey Whitzer, Subhrajit Bhattacharya and Vijay Kumar, “*Sensor Coverage of Unknown Environments by Robot Swarms Using Limited Local Sensing*”, In Proceedings of IEEE International Conference on Robotics and Automation (ICRA), May 2015.
17. Vijay Govindarajan, Subhrajit Bhattacharya and Vijay Kumar, “*Human-Robot Collaborative Topological Exploration for Search and Rescue Applications*”, In International Symposium on Distributed Autonomous Robotic Systems (DARS), November 2014.
18. Chanyoung Jun, Subhrajit Bhattacharya and Robert Ghrist, “*Pursuit-Evasion Game for Normal Distributions*”, In Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), September 2014.
19. Soonkyum Kim, Subhrajit Bhattacharya and Vijay Kumar, “*Path Planning for a Tethered Mobile Robot*”, In Proceedings of IEEE International Conference on Robotics and Automation (ICRA), May 2014.
20. Soonkyum Kim, Subhrajit Bhattacharya, Robert Ghrist and Vijay Kumar, “*Topological Exploration of Unknown and Partially Known Environments*”, In Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). Tokyo, Japan, November 3-7, 2013.
21. Soonkyum Kim, Subhrajit Bhattacharya and Vijay Kumar, “*Dynamic Simulation of Autonomous Boats for Cooperative Skimming and Cleanup*”, In Proceedings of the ASME 2013 International Design Engineering Technical Conferences (IDETC), Portland, USA, August 4-7, 2013.
22. Soonkyum Kim, Subhrajit Bhattacharya, Hordur Heidarsson, Gaurav Sukhatme and Vijay Kumar, “*A Topological Approach to Using Cables to Separate and Manipulate Sets of Objects*”. In Proceedings of the Robotics: Science and System (RSS), Sydney, Australia, June 24-28, 2013.
23. Soonkyum Kim, Koushil Sreenath, Subhrajit Bhattacharya and Vijay Kumar, “*Optimal Trajectory Generation Under Homology Class Constraints*”, In 51st IEEE Conference on Decision and Control. 10-13 Dec., 2012.
24. Soonkyum Kim, Koushil Sreenath, Subhrajit Bhattacharya and Vijay Kumar, “*Trajectory Planning for Systems*

- with Homotopy Class Constraints*". In 13th International Symposium on Advances in Robot Kinematics (ARK), Innsbruck, Austria, June 2012, Springer, Netherlands, pages 83-90.
25. Subhrajit Bhattacharya, Robert Ghrist and Vijay Kumar, "*Multi-Robot Coverage and Exploration in Non-Euclidean Metric Spaces*", In Proceedings of The Tenth International Workshop on the Algorithmic Foundations of Robotics (WAFR). 13-15 June, 2012.
  26. Subhrajit Bhattacharya, Maxim Likhachev and Vijay Kumar, "*Identification and Representation of Homotopy Classes of Trajectories for Search-based Path Planning in 3D*" (Original title: *Identifying Homotopy Classes of Trajectories for Robot Exploration and Path Planning*) [*Winner of Best Paper Award*], In Proceedings of Robotics: Science and Systems. 27-30 June, 2011.
  27. Subhrajit Bhattacharya, Hordur Heidarsson, Gaurav S. Sukhatme and Vijay Kumar, "*Cooperative Control of Autonomous Surface Vehicles for Oil Skimming and Cleanup*", In Proceedings of IEEE International Conference on Robotics and Automation (ICRA). 9-13 May, 2011.
  28. Subhrajit Bhattacharya, Nathan Michael and Vijay Kumar, "*Distributed Coverage and Exploration in Unknown Non-Convex Environments*", In Proceedings of 10th International Symposium on Distributed Autonomous Robotics Systems. 1-3 Nov 2010, Springer.
  29. Subhrajit Bhattacharya, Vijay Kumar and Maxim Likhachev, "*Search-based Path Planning with Homotopy Class Constraints*", In Proceedings of The Third Annual Symposium on Combinatorial Search, [*non-archival*]. Atlanta, Georgia, 8-10 July, 2010.
  30. Subhrajit Bhattacharya, Vijay Kumar and Maxim Likhachev, "*Search-based Path Planning with Homotopy Class Constraints*". In Proceedings of The Twenty-Fourth AAAI Conference on Artificial Intelligence. Atlanta, Georgia, 11-15 July, 2010.
  31. Subhrajit Bhattacharya, Vijay Kumar and Maxim Likhachev, "*Distributed Optimization with Pairwise Constraints and its Application to Multi-robot Path Planning*". In Proceedings of Robotics: Science and Systems. Zaragoza, Spain, 27-30 June 2010, MIT Press.
  32. Subhrajit Bhattacharya, Maxim Likhachev and Vijay Kumar, "*Multi-agent Path Planning with Multiple Tasks and Distance Constraints*". In Proceedings of IEEE International Conference on Robotics and Automation (ICRA). Anchorage, Alaska, 3-8 May 2010.
  33. Paul Vernaza, Maxim Likhachev, Subhrajit Bhattacharya, Sachin Chitta, Aleksandr Kushleyev and Daniel D. Lee, "*Search-based planning for a legged robot over rough terrain*". In Proceedings of IEEE International Conference on Robotics and Automation (ICRA), pages 2380-2387, 12-17 May 2009.
  34. Subhrajit Bhattacharya, Sachin Chitta, Vijay Kumar and Daniel Lee, "*Optimization of a Planer Quadruped Dynamic Leap*" [*Winner of MSC Simulation Software Award*], In Proceedings of 2008 ASME International Design Engineering Technical Conferences (IDETC), New York City, NY, 3-6 August, 2008.
  35. Subhrajit Bhattacharya, "*A Study on Effect of Stiffener Geometry on the Modal Frequencies of a Rotating Disk with Radial Stiffeners using FEM and Analytical Methods*", Proceedings of Ninth International Conference on Recent Advances in Structural Dynamics, University of Southampton on July 2006.
  36. Subhrajit Bhattacharya, "*A study on a generalized wave equation for disturbances propagating through a one-dimensional medium placed in a two-dimensional space*", Proceedings of International Conference on Theoretical, Applied, Computational and Experimental Mechanics, p. 235-237, Indian Institute of Technology, Kharagpur, 2004.

#### Editorials

1. Subhrajit Bhattacharya, Florian T. Pokorny and Howie Choset, "*Guest Editorial: Special issue on Topological Methods in Robotics*". Autonomous Robots (AURO) Springer, 45:611-612, 2021.

#### Selected Preprints

1. Alp Sahin and Subhrajit Bhattacharya, "*Optimal Path Planning in Distinct Topo-Geometric Classes using Neighborhood-augmented Graph and its Application to Path Planning for a Tethered Robot in 3D*", Electronic Pre-print, June 2023. arXiv:2306.01203 [cs.RO].
2. Xiaolong Wang, Alp Sahin and Subhrajit Bhattacharya, "*Coordination-free Multi-robot Path Planning for Congestion Reduction Using Topological Reasoning*", Electronic Pre-print, 2022. arXiv:2205.00955 [cs.RO]. [Com-

- plete publication in Journal of Intelligent and Robotic Systems (JINT), Springer Nature, 2023.]*
3. Zhan Gao, Subhrajit Bhattacharya, Leiming Zhang, Rick Blum, Alejandro Ribeiro and Brian M. Sadler, “*Training Robust Graph Neural Networks with Topology Adaptive Edge Dropping*”, Electronic Pre-print, June, 2021. arXiv:2106.02892 [cs.LG].
  4. Leiming Zhang, Amanda Prorok and Subhrajit Bhattacharya, “*Pursuer Assignment and Control Strategies in Multi-agent Pursuit-Evasion Under Uncertainties*”, Electronic Pre-print, March, 2021. arXiv:2103.15660 [cs.RO]. [*Complete publication in IEEE International Symposium on Multi-Robot and Multi-Agent Systems, 2019.*]
  5. Subhrajit Bhattacharya, “*On Some Bounds on the Perturbation of Invariant Subspaces of Normal Matrices with Application to a Graph Connection Problem*”, Electronic Pre-print, March, 2021. arXiv:2103.09413 [cs.SP]. [*Complete publication in Journal of Inequalities and Applications (JIAP), Springer, 2022.*]
  6. Mohammad S. Teymouri and Subhrajit Bhattacharya, “*Landmark-based Distributed Topological Mapping and Navigation in GPS-denied Urban Environments Using Teams of Low-cost Robots*”, Electronic Pre-print, 2021. arXiv:2103.03741 [cs.RO].
  7. Leiming Zhang, Brian M. Sadler, Rick S. Blum and Subhrajit Bhattacharya, “*Inter-cluster Transmission Control Using Graph Modal Barriers*”, Electronic Pre-print, Oct, 2020. arXiv:2010.04790 [cs.SI]. [*Complete publication in IEEE Transactions on Signal and Information Processing over Networks (T-SIPN), 2021.*]
  8. Subhrajit Bhattacharya and Robert Ghrist, “*Path Homotopy Invariants and their Application to Optimal Trajectory Planning*”, Electronic Pre-print, 2017. arXiv:1710.02871 [cs.RO]. [*Complete publication in Annals of Mathematics and Artificial Intelligence (AMAI), Springer International Publishing, 2018.*]
  9. Subhrajit Bhattacharya, “*Approximate Structure Construction Using Large Statistical Swarms*”, Electronic Pre-print, June, 2017. arXiv:1706.03842 [cs.RO].
  10. Subhrajit Bhattacharya, “*A Search Algorithm for Simplicial Complexes*”, Electronic preprint, July 2016. arXiv:1607.07009 [cs.DM]. [*Complete publication in International Journal of Robotics Research (IJRR), SAGE Publishers, 2019.*]
  11. Subhrajit Bhattacharya, “*A General Continuous Inverse Kinematics Algorithm for a Planar Robot Arm*”, Electronic Pre-print, September, 2013-14. [*Complete publication in Acta Applicandae Mathematicae, 2014, Springer Netherlands.*]
  12. Subhrajit Bhattacharya and Mihail Pivtoraiko, “*A Classification of Configuration Spaces of Planar Robot Arms with Application to a Continuous Inverse Kinematics Problem*”, Electronic preprint, September 2013. arXiv:1309.7960 [math.DG] [*Complete publication in Acta Applicandae Mathematicae, September 2014, Springer Netherlands.*]
  13. Subhrajit Bhattacharya, David Lipsky, Robert Ghrist and Vijay Kumar, “*Invariants for Homology Classes with Application to Optimal Search and Planning Problem in Robotics*”, Electronic preprint, 2012, arXiv: 1208.0573 [math.AT] [*Complete publication in Annals of Mathematics and Artificial Intelligence, 2013.*]
  14. Subhrajit Bhattacharya, Robert Ghrist and Vijay Kumar, “*Relationship Between Gradient of Distance Functions and Tangents to Geodesics*”, Electronic preprint, 2012. [*Complete publication in International Journal of Robotics Research (IJRR), 33(1):113-137, October 2013, SAGE Publishers.*]

#### HONORS AND AWARDS

1. **NSF CAREER Award** on “*Topological Abstraction for Robot Path Planning*”. (May 2022)
2. **Best Paper Award** at the seventh Robotics: Science and Systems (RSS), University of Southern California, Los Angeles. (June 2011)
3. **MSC Simulation Software Award** at the 2008 ASME International Design Engineering Technical Conferences (IDETC), New York City, NY. (August 2008)
4. **Best Paper Award (students’)** at Second World Congress on Lateral Computing, 2005, Bangalore. (Dec, 2005)

## RESEARCH FUNDING

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### Extramural

#### Competitively Awarded Research Grants (Current & Past):

1. “*Transmission Control in Complex Networks Using Modal Methods*”, Air Force Office of Scientific Research, \$498,433, 2022-2025. PI: Subhrajit Bhattacharya; co-PI: Rick Blum (Lehigh U.).
2. “*CAREER: Topological Abstraction for Robot Path Planning*”, National Science Foundation (FRR program), \$500,246, 2022-2027. PI: Subhrajit Bhattacharya.
3. “*Topological Representations and Algorithms for Robot Swarms*”, Office of Naval Research, \$613,126, 2014-16. PI: Vijay Kumar (U. of Pennsylvania); Senior/key person (in capacity of co-PI): Subhrajit Bhattacharya.
4. “*Human-robot peer-to-peer communication and coordination for tactical operations in urban environment*”, Army Research Laboratory, \$100,000 / year, 2009-17. PI: Dr. Vijay Kumar; Senior/key person (in capacity of co-PI): Subhrajit Bhattacharya.

#### Extramural Contract/Consulting Work:

1. “*Topological Representations and Algorithms for Robot Swarms*”, subaward from University of Pennsylvania, \$60,000 for 1 year, 2016-17. PI: Subhrajit Bhattacharya.

### Intramural

#### Competitively Awarded Research Grants (Current & Past):

1. “*PITA XXIV: Intelligence and Autonomy Development for a Snake-like Cobot with Inspection and Maintenance Applications*”, Pennsylvania Infrastructure Technology Alliance, \$43,450, 2022-2023. PI: Subhrajit Bhattacharya; co-PI: Aparna Bharati (Lehigh U.); Industrial Partner: Matthew Bilsky (FLX Solutions, Inc.).
2. “*PITA XXIII: User-friendly Cobot Control Algorithms for Inspection and Repair Snake-like Robots*”, Pennsylvania Infrastructure Technology Alliance, \$44,550, 2021-2022. PI: Subhrajit Bhattacharya (Lehigh U.); Industrial Partner: Matthew Bilsky (FLX Solutions, Inc.).
3. “*PITA XXII: Algorithm Development for a Low-Cost, 3D Printed Snake-Like Robot for Inspection and Repair*”, Pennsylvania Infrastructure Technology Alliance, \$49,500, 2020-2021. PI: Subhrajit Bhattacharya (Lehigh U.); Industrial Partner: Matthew Bilsky (FLX Solutions, Inc.).
4. “*PITA XX: Systems-level Development of a Snake-like Robot with Construction, Inspection, Aerospace, and Disaster Recovery Applications*”, Pennsylvania Infrastructure Technology Alliance, \$40,000, 2018-2019. PI: Subhrajit Bhattacharya (Lehigh U.); Industrial Partner: Matthew Bilsky (FLX Solutions, Inc.).

## EDITOR/EDITORIAL REVIEW BOARD MEMBERSHIPS

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1. Subhrajit Bhattacharya, Florian T. Pokorny and Howie Choset, “*Guest Editorial: Special issue on Topological Methods in Robotics*”. *Autonomous Robots (AURO)* Springer, 45:611-612, 2021.

## SCHOLARLY PRESENTATIONS

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### Invited Presentations

1. Subhrajit Bhattacharya, “*Planning and Control on Riemannian Manifolds with Boundaries*” at the workshop on “Bringing geometric methods to robot learning, optimization and control” at the 2020 International Conference on Intelligent Robots and Systems (IROS).
2. Subhrajit Bhattacharya, “*Topological Representations in Planning*” at the weekly seminar of the Search-based Planning Lab, Robotics Institute, Carnegie Mellon University, Nov 22, 2019.
3. Subhrajit Bhattacharya, “*Recent Advances in Topological Path Planning*” at the 2018 AMS Sectional Meeting on Applied Algebraic Topology, Newark, Delaware, September 29-30, 2018..
4. Subhrajit Bhattacharya, “*Some Applications of Topological Motion Planning*” at the Topological Robotics seminar, Department of Mathematics, Lehigh University, April 2017.
5. Subhrajit Bhattacharya, “*Homotopy Invariants and Their Applications to Optimal Motion Planning*” at the Topological Robotics seminar, Department of Mathematics, Lehigh University, October 2016.
6. Subhrajit Bhattacharya, “*Topological Methods in Robot Motion Planning*” at the EECS Friday seminar, University of California, Berkeley, January 15, 2016.

7. Subhrajit Bhattacharya, “*Path Homotopy Invariants and their Application to Optimal Trajectory Planning*” at the Applied Topology Seminar, University of Pennsylvania, October 19, 2015.
8. Subhrajit Bhattacharya, “*Effective path planning for end effector of high-DOF planar robot arms through Reeb graph construction*” at the Mathematics Colloquium, Lehigh University, April 22, 2015.
9. Subhrajit Bhattacharya, “*Topological Techniques in Graph Search-based Motion Planning*” at the Geometry-Topology Seminar, University of Pennsylvania, Feb 12, 2015.
10. Subhrajit Bhattacharya, “*Topological Techniques in Graph Search-based Robot Planning*” at the IMA Annual Workshop on “Topological Systems: Communication, Sensing, and Actuation”, University of Minnesota, March 3-7, 2014.
11. Subhrajit Bhattacharya, “*Topological Techniques in Graph Search-based Planning*” as part of the Center for Foundations of Robotics’ seminar series at the Carnegie Mellon University, Pittsburgh, Nov 18, 2013.
12. Subhrajit Bhattacharya, Maxim Likhachev and Vijay Kumar “*Search-based Path Planning with Homotopy Class Constraints in 3D*” at the sub-area spotlights track on ‘Best-paper talks’ of the Twenty-Sixth Conference on Artificial Intelligence (AAAI-12), July 22-26, 2012. [*Because of inability to travel, the presentation was made by Prof. Maxim Likhachev.*]
13. Subhrajit Bhattacharya, A talk on the ‘Littledog’ Robot and ‘Learning Locomotion’ project for an undergraduate level class on robotics at the Swarthmore College, Pennsylvania, April 15, 2008. Invited by Prof. Ani M. Hsieh.

### Organized or Chaired Sessions

1. *Chair*; sessions on “UAS Control - I” and “UAS Applications - V”, at the 2017 International Conference on Unmanned Aircraft Systems (ICUAS), June 13-16, 2017.

### Workshops and Tutorial Talks:

1. “*Recent Advances in Topological Path Planning*” at the Workshop on *Topological Methods in Robot Planning*, IEEE International Conference on Robotics and Automation (ICRA), May 2019. (co-organized by Subhrajit Bhattacharya, Florian T. Pokorny and Vijay Kumar).
2. “*Topological motion planning*” at the Workshop on *Emerging Topological Techniques in Robotics*, IEEE International Conference on Robotics and Automation (ICRA), May 2016. (Workshop co-organized by Subhrajit Bhattacharya, Vijay Kumar, Florian T. Pokorny and Subramanian Ramamoorthy).

## TEACHING AND RESEARCH ADVISING

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### Teaching

#### Courses Taught:

- ME 295: Mathematical Applications in Mechanical Engineering; Spring 2023, Lehigh University. *Instructor.* Description: *Undergraduate-level course on applications of differential equation in mechanical engineering problems.*
- Mech 102: Dynamics; Fall 2023, 2022, 2021, 2020, 2019, 2018, 2017, 2016, Lehigh University. *Instructor.* Description: *Undergraduate-level course on Dynamics.*
- ME 450: Robot Motion Planning and Control; Fall 2023, 2021, 2020, 2019, 2018, Lehigh University. *Instructor.* Description: *Graduate-level course on motion planning, coverage exploration and control.*
- Mech 425: Analytical Methods in Dynamics and Vibrations; Spring 2023, 2022, 2021, 2020, 2019, 2017, Lehigh University. *Instructor.* Description: *Graduate-level course on Dynamics and Vibration, covering topics that include Lagrangian & Hamiltonian mechanics and rigid-body dynamics.*
- Math 114: Calculus II; Spring 2016, University of Pennsylvania. *Instructor.* Description: *Undergraduate-level course on vector and multi-variable calculus.*
- Math 170: Ideas in Mathematics; Fall 2015, 2014 University of Pennsylvania. *Instructor.* Description: *Undergraduate-level course on topics in mathematics including sets theory, logic, topology, graph theory, geometry, and their applications.*
- MEAM 899: Introduction to Topology and Differential Geometry for Application to Robotics; Fall 2014, University of Pennsylvania. *Instructor.* Description: *Graduate-level independent study for first and second year graduate students pursuing research in Robotics.*
- Engineering Pre-freshman Program on Mathematics; Summer 2014, University of Pennsylvania. *Co-instructed*

with Dr. Robert Ghrist and Dr. Vidit Nanda. Description: *Math 103 level undergraduate calculus course for incoming first year undergraduate students.*

- MEAM 899: Independent study on Topics in Robotics; Fall 2012, University of Pennsylvania. *Co-instructed with Dr. Koushil Sreenath and Steven Gray. Description: Graduate-level independent study for first and second year graduate students pursuing research in Robotics. Was responsible for lectures on “Configuration Spaces and Topology”.*

*Teaching Assistant:*

- “Calculus: Single Variable”; Summer 2014, Spring 2014. Coursera massive open online course (MOOC) instructed by Prof. Robert Ghrist.
- MEAM 535: Advanced Dynamics; Fall 2010, Fall 2007. Graduate level course instructed by Prof. Vijay Kumar and Prof. Michael A. Carchidi.
- CSE 390: Robotics and Automation; Fall 2008. Graduate & undergraduate level course instructed by Prof. Jonathan Fiene and Prof. Jianbo Shi.
- MEAM 211: Engineering Mechanics: Dynamics; Spring 2008. Undergraduate level course instructed by Prof. Michael A. Carchidi and Prof. Jonathan Fiene.

*Outreach:*

- A “Capture-the-flag” Activity using a Team of Ground Robots for Teaching Fundamentals of Robot Motion Planning and Control; June 2023, Lehigh University. *Principal Organizer, Instructor at the 2023 Lehigh CHOICES camp. Description: CHOICES is a engineering and science outreach program for middle-school girls.*
- Presentations and demonstrations at the AIR lab for the LWE PreLUision program; July 2022, Lehigh University. *co-organizer. Description: PreLUision is a summer pre-orientation experience offered for female students starting at Lehigh in the Fall.*
- Delivered lessons on “Fundamentals of Robot Motion Planning and Control” and organized a “Capture-the-flag” Activity using a Team of Ground Robots; June 2022, Lehigh University. *Principal Organizer, Instructor at the 2022 Lehigh CHOICES camp. Description: CHOICES is a engineering and science outreach program for middle-school girls.*
- Short course: Fundamentals of Robot Motion Planning and Control; March 2021, Lehigh University. *Instructor at the 2021 Lehigh CHOICES camp. Description: CHOICES is a engineering and science outreach program for middle-school girls.*

**Advising**

***Doctoral Students:***

1. *Alp Sahin* (Fall 2021 – present)
2. *Shunsaku Yadoko* (Summer 2023 – present)
3. *Mobin Habibpour* (incoming student, starting in Fall 2023)
4. *Xiaolong Wang* (Fall 2018 – March 2022)
5. *Leiming Zhang* – Graduated (Spring 2018 – August 2021)
6. *Rattanachai Ramaithitima* – Graduated from University of Pennsylvania; Co-advised with Dr. Vijay Kumar (2016 – 2019)

***Masters Students:***

1. *Zhenyu Jin* (Fall/Winter 2022). Research topic: *Control Algorithms of a Snake-like Robot.*
2. *Chenkai Ou* (Summer 2022). Research topic: *Joystick-based User-interface Development for a Snake-like Robot.*
3. *MohammadSaleh Teymouri* (Fall 2017 – Summer 2021). Research topic: *Towards Optimal Landmark Distribution for Landmark-based Localization and Mapping with Directional Sensors.*
4. *Yutian Wang* (Spring 2019 – Summer 2020). Research topic: *Analysis of Configuration Classes and Numerical Computation of Vital Critical Points for a Planar Robotic Arm in a Domain with Point Obstacles.*
5. *Sagar Jagina* (Spring 2018 – Spring 2019). Research topic: *Reconstruction of Euclidean Embedding of a Landmarks Complex from Noisy Distance Measurements.*



6. Xiaolong Wang (Summer 2017 – Spring 2018). Research topic: *A Topological Approach to Workspace and Motion Planning for a Cable-controlled Robot in Cluttered Environments*.
7. Leiming Zhang (Summer & Fall 2017) Research topic: *Multi-agent Pursuit-Evasion Under Sensing Uncertainties*.
8. Bo Tian (Summer 2017 – Spring 2018) Research topic: *Shape Control of a Spatial Cable*.
9. Chengwei Zhao (Fall 2017) : Research topic: *Visual Homing based Control of Spatial Robots*.

**Undergraduate Students:**

1. Nick Kozachuk (Summer 2023): Research topic: *Adversarial Resonance Attack in Networks with Second Order Dynamics*.
2. Jitong Ding (Summer 2021): Research topic: *Multi-robot experimentation for “Topological Trajectory Planning for Large Swarms in Dynamic Unpredictable Environments”*.
3. Jennie-Rose Barrella (Fall 2017): Research topic: *Assembly, testing and controller development for a Raspberry Pi based robot*.
4. Brook Glassman (Summer/Fall 2017): Research topic: *Assembly, testing and controller development for a Raspberry Pi based robot*.
5. Xinyue Shi (Spring 2017): Research topic: *Development and Testing of Controllers and Algorithms for a Quad-Copter*.
6. Vijay Govindarajan – Co-supervised with Prof. Vijay Kumar (Spring 2013 – Spring 2015), University of Pennsylvania

SERVICE

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**University**

*Service to University:*

- *Member, Disciplinary Appeals Committee*, Lehigh University, Fall 2017 - Summer 2021.
- *Member, Algebraic Geometry Search Committee*, Department of Mathematics, Lehigh University, Fall 2017.

*Service to College:*

- *Member, Robotics Search Committee*, Lehigh University, Fall 2022 - Spring 2023.
- *Member, CSE Department Search Committee*, Lehigh University, Fall 2020.
- *Member, CSE Department Search Committee*, Lehigh University, Fall 2019 - Spring 2020.
- *Member, Robotics and Controls Search Committee*, College of Engineering and Applied Science, Lehigh University, Fall 2018-2019.
- *Member, Robotics and Controls Search Committee*, College of Engineering and Applied Science, Lehigh University, Fall 2017-2018.

*Service to Department:*

- *Member, Graduate Curriculum & Advisory Committee*, Mechanical Engineering and Mechanics, Lehigh University, Fall 2016-present.

**Professional**

- *Lead guest editor*, special issue on “Topological Methods in Robotics”, *Autonomous Robots*, Springer, May 2019 - June 2021.
- *Co-organizer*, Workshop on “Geometry and Topology in Robotics: Learning, Optimization, Planning, and Control”, *Robotics Science and Systems (RSS)*, July 2021.
- *Senior Program Committee member*, 29th International Joint Conference on Artificial Intelligence and the 17th Pacific Rim International Conference on Artificial Intelligence (IJCAI-PRICAI), 2020.
- *Co-organizer*, Workshop on “Topological Methods in Robot Planning”, *IEEE International Conference on Robotics and Automation (ICRA)*, May 2019.
- *Proposal review panel member*, National Science Foundation (NSF), June 2018, February 2022, March 2023.
- *Ad-hoc proposal reviewer*, Army Research Office, Sept 2021.
- *Chair*, sessions on “UAS Control - I” and “UAS Applications - V”, at the 2017 International Conference on

Unmanned Aircraft Systems (ICUAS), June 13-16, 2017.

- *Member of Doctoral Thesis Committees*: Kaier Liang (MEM, Lehigh U., Spring 2023 – present); Disha Kamale (MEM, Lehigh U., Fall 2022 – present); Gustavo A. Cardona (MEM, Lehigh U., Fall 2022 – present); Sudarshan Kalidoss (MEM, Lehigh U., Spring 2018 – Spring 2023); Onur Denizhen (MEM, Lehigh U., Spring 2017 – present); Yaser Ghaedsharaf (MEM, Lehigh U., Fall 2018 – Spring 2019, graduated in Spring 2019); Monroe Kennedy III (U. of Pennsylvania, Fall 2017 – Spring 2019, graduated in Spring 2019); Hossein K. Mousavi (MEM, Lehigh U., Fall 2017 – Fall 2019, graduated in Fall 2019); Mirsaleh Bahavarnia (MEM, Lehigh U., Spring 2017 – Spring 2018, graduated in Spring 2018); Robert Short (Department of Mathematics, Lehigh U., Spring 2017 – Spring 2018, graduated in Spring 2018); Dhanushka Kularatne (Drexel U., Fall 2016 – Fall 2017, graduated in Fall 2017);
- *Interviewer*, Penn Alumni Interview Program, 2017.
- Reviewer for *IEEE International Conference on Intelligent Robots and Systems (IROS)* 2011–2016, 2018, 2020–2023; *Journal of Intelligent and Robotic Systems (JINT)*, Springer 2023; *IEEE Robotics and Automation Letters (RA-L)* 2016–2022; *IEEE International Conference on Robotics and Automation (ICRA)* 2011–2018, 2021–2023; *IEEE Transactions on Robotics (T-RO)*: 2012, 2014, 2019, 2022; *J. Renewable Energy (RENE)* 2021, 2022; *Robotics: Science and Systems (RSS)* 2021, 2023; *Autonomous Agents and Multi-agent Systems*, Springer 2019; *Robotics and Autonomous Systems* 2019; *IEEE International Symposium on Multi-robot and Multi-agent Systems* 2019; *Autonomous Robots (AURO)*, Springer 2012, 2016, 2017, 2019; *Journal of Applied Soft Computing* 2018; *International Conference on Unmanned Aircraft Systems (ICUAS)* 2018; *American Control Conference* 2018; *Indian Control Conference (ICC)*, 2018; *IEEE Transactions on Cybernetics* 2017; *Signal Processing Letters (SPL)* 2017; *Computational and Applied Mathematics (A Springer journal)* 2017; *Robotica (Cambridge University Press)* 2016, 2017; *Mediterranean Conference on Control and Automation (MED)* 2017; *International Journal of Robotics Research (IJRR)*: 2011, 2012, 2015 & 2016; *International Journal of Mechanical Engineering (IJME)* 2016; *Automatica (An Elsevier journal)* 2015; *IEEE Conference on Decision and Control (CDC)* 2012 & 2013; *Tenth International Workshop on the Algorithmic Foundations of Robotics (WAFR)* 2012; *IEEE International Conference on Automation Science and Engineering (CASE)* 2011; *Distributed Autonomous Robotic Systems (DARS)* 2012; *ASME Journal of Dynamic Systems, Measurement and Control*: 2013; *ACM Transactions on Sensor Networks (TSN)*: 2012; *Proceedings of the National Academy of Sciences, India, Section A: Physical Sciences*: 2015; *ASME Journal of Mechanical Design*: 2015; *IEEE Transactions on Automatic Control*: 2015; *A TOP Grant Module submitted to The Netherlands Organisation for Scientific Research (NWO)* 2014.
- *Open-source Development and Community Projects*: *i.* Developer and maintainer of the DOSL (Discrete Optimal Search Library) C++ library [Project page: <https://github.com/subh83/DOSL>]; *ii.* A contributor to the PmWiki content management system – developed several modules for this wiki project [User page: <http://www.pmwiki.org/wiki/Profiles/Subhrajit>]; *iii.* A contributor to Wikipedia [User page: <http://en.wikipedia.org/wiki/User:Subh83>]
- *Co-organizer*, Workshop on “Emerging Topological Techniques in Robotics”, IEEE International Conference on Robotics and Automation (ICRA), May 2016.
- *Member of Conference Program Committees*: “International Symposium on Combinatorial Search” (SoCS), 2015, 2016, 2017, 2019; “Distributed Autonomous Robotic Systems” (DARS) conference, 2016; “International Joint Conference on Artificial Intelligence” (IJCAI) conference, 2016, 2020; “Intelligent Robotics and Multi-Agent Systems” (IRMAS) track of “ACM Symposium on Applied Computing” (SAC), 2016; “Robotics: Science and Systems” (RSS) conference, 2014;
- *Prize Committee*, Department of Mathematics, University of Pennsylvania, 2014-15.
- Volunteer for the The Twenty-Fourth AAAI Conference on Artificial Intelligence, 2010.

#### *Other Professional Experiences:*

- *Participant, member of the “Low-cost 3D Printed Snake-like Robots for Inspection and Repair” team*, I-Corps Short Course, organized by New York City Regional Innovation Node (NYCRIN), Summer 2019.