

# HENG YANG

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Laboratory for Information & Decision Systems ◊ Massachusetts Institute of Technology

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## EDUCATION

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### Ph.D. in Mechanical Engineering

Massachusetts Institute of Technology, Cambridge, MA

*Major:* Robotics

*Minor:* Optimization and Machine Learning

9/2017–Present

Advisor: Luca Carlone

### M.S. in Mechanical Engineering

Massachusetts Institute of Technology, Cambridge, MA

8/2015–6/2017

Advisor: Brian W. Anthony

### B.E. in Vehicle Engineering

Tsinghua University, Beijing, China

8/2011–7/2015

GPA: 94.3/100, Rank: 1/93

Graduated with highest honors, Tsinghua Principal Scholarship (9/3000+)

## RESEARCH INTERESTS

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I am broadly interested in robotics, computer vision, optimization, and learning. My research vision is to enable *safe and trustworthy autonomy* for a broad range of *high-integrity applications* (e.g., autonomous driving, space robotics), by designing *tractable and provably correct algorithms* that enjoy *rigorous performance guarantees*, developing fast implementations, and validating them on *real robotic systems*.

My PhD research focuses on designing *certifiable algorithms* for *outlier-robust geometric estimation* in robot perception. Despite the *NP-hardness* of the *mathematical optimization* problems involved in outlier-robust geometric estimation, my *certifiable algorithms* are the first *polynomial-time* algorithms that either provide a certificate of optimality or declare failure when such a certificate cannot be provided. This is crucial for safety-critical applications where detecting potential failures is paramount. I have established the *theoretical and computational foundations* of certifiable perception based on a set of advanced mathematical tools (e.g., robust estimation, semidefinite relaxation, large-scale convex optimization solvers), and successfully demonstrated the trustworthiness of certifiable algorithms on safety-critical applications such as self-driving and space robotics.

My current and future research aims to start from certifiable perception, and reach my vision of safe and trustworthy autonomy, by building an *advanced toolbox combining theory, computation, and system validation*. I plan to execute two important steps towards this goal. The first step aims to integrate *certifiable perception* with *deep feature learning* to achieve safe learning-based perception, and the second step aims to integrate *safe perception* with *safe action* to construct system-level safety guarantees.

## AWARDS AND RECOGNITIONS

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- I was featured by [MIT Spotlight](#) (front page of MIT) for *making self-driving cars safer through keener robot perception*, 2021.
- I was selected as a [Robotics: Science and Systems \(RSS\) Pioneer](#), 2021.
- The paper “*Optimal Pose and Shape Estimation for Category-level 3D Object Perception*” won a [Best Paper Award Finalist](#) at Robotics: Science and Systems (RSS), 2021.
- The paper “*Graduated Non-Convexity for Robust Spatial Perception: From Non-Minimal Solvers to Global Outlier Rejection*” received a [Best Paper Award Honorable Mention](#) from IEEE Robotics and Automation Letters (RA-L), 2021.

- I was selected as a Finalist of MIT’s first [Research Slam public showcase](#) featuring 3-minute thesis. Talk title: *Certifiable perception: towards safe and trustworthy autonomy*, 2021. ([video](#))
- The paper “*Graduated Non-Convexity for Robust Spatial Perception: From Non-Minimal Solvers to Global Outlier Rejection*” won the [Best Paper Award in Robot Vision](#) at the International Conference on Robotics and Automation (ICRA), 2020. Algorithms in the paper have been commercialized by MathWorks in the [Navigation Toolbox](#) of Matlab 2020b, and featured in the Mathworks news story [Trusting Robots to Navigate New Spaces](#), 2021.
- The paper “*A Polynomial-time Solution for Robust Registration with Extreme Outlier Rates*”, published at Robotics: Science and Systems (RSS) 2019, was featured on [MIT News Spotlight](#), [LIDS News](#), and [ScienceDaily](#), in the story [Spotting objects amid clutter](#), 2019.
- Personal feature “*Heng Yang: Really care about curiosity and constantly ask questions about the world*” on [Tsinghua News Spotlight](#) and [People’s Daily Education](#), 2015.
- Tsinghua Principal Scholarship (*highest honor for undergraduates, 9 awarded out of 3000+*), 2015.

## SELECTED PUBLICATIONS AND PREPRINTS

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- [1] H. Yang and L. Carlone, “Certifiable Outlier-Robust Geometric Perception: Exact Semidefinite Relaxations and Scalable Global Optimization,” *IEEE Trans. Pattern Anal. Machine Intell.*, 2021, Minor Revision. ([pdf](#)), ([code](#))
- [2] H. Yang, L. Liang, L. Carlone, and K.-C. Toh, “An Inexact Projected Gradient Method with Rounding and Lifting by Nonlinear Programming for Solving Rank-One Semidefinite Relaxation of Polynomial Optimization,” *Mathematical Programming*, 2021, submitted. ([pdf](#)), ([code](#))
- [3] J. Shi, H. Yang, and L. Carlone, “Optimal Pose and Shape Estimation for Category-level 3D Object Perception,” in *Robotics: Science and Systems (RSS)*, 2021, *Best Paper Award Finalist*. ([pdf](#))
- [4] H. Yang, W. Dong, L. Carlone, and V. Koltun, “Self-supervised Geometric Perception,” in *IEEE Conf. on Computer Vision and Pattern Recognition (CVPR)*, 2021, *Oral Presentation*. ([pdf](#)), ([code](#))
- [5] J. Shi, H. Yang, and L. Carlone, “ROBIN: a Graph-Theoretic Approach to Reject Outliers in Robust Estimation using Invariants,” in *IEEE Intl. Conf. on Robotics and Automation (ICRA)*, 2021, ([pdf](#))
- [6] H. Yang and L. Carlone, “One Ring to Rule Them All: Certifiably Robust Geometric Perception with Outliers,” in *Conference on Neural Information Processing Systems (NeurIPS)*, 2020, ([pdf](#)), ([code](#)), ([video](#))
- [7] H. Yang, J. Shi, and L. Carlone, “TEASER: Fast and Certifiable Point Cloud Registration,” *IEEE Trans. Robotics*, 2020, ([pdf](#)), ([code](#))
- [8] P. Antonante, V. Tzoumas, H. Yang, and L. Carlone, “Outlier-Robust Estimation: Hardness, Minimally-Tuned Algorithms, and Applications,” *IEEE Trans. Robotics*, 2021, ([pdf](#)), ([code](#)), ([code](#)), ([code](#))
- [9] H. Yang, P. Antonante, V. Tzoumas, and L. Carlone, “Graduated Non-Convexity for Robust Spatial Perception: From Non-Minimal Solvers to Global Outlier Rejection,” *IEEE Robotics and Automation Letters (RA-L)*, vol. 5, no. 2, pp. 1127–1134, 2020, *Best Paper Award in Robot Vision at ICRA 2020*, *Best Paper Award Honorable Mention from RA-L 2020*, featured by *Mathworks News*. ([pdf](#)), ([code](#)), ([media](#))
- [10] H. Yang and L. Carlone, “In Perfect Shape: Certifiably Optimal 3D Shape Reconstruction from 2D Landmarks,” in *IEEE Conf. on Computer Vision and Pattern Recognition (CVPR)*, 2020, ([pdf](#))
- [11] H. Yang and L. Carlone, “A Quaternion-based Certifiably Optimal Solution to the Wahba Problem with Outliers,” in *Intl. Conf. on Computer Vision (ICCV)*, 2019, pp. 1665–1674, *Oral Presentation (4.6%)*. ([pdf](#))

- [12] H. Yang and L. Carlone, “A Polynomial-time Solution for Robust Registration with Extreme Outlier Rates,” in *Robotics: Science and Systems (RSS)*, 2019, *Spotlight Presentation, featured by MIT News Spotlight front page*. ([pdf](#)), ([video](#)), ([media](#)), ([media](#)), ([media](#)), ([media](#))
- [13] H. Yang, C. Doran, and J.-J. E. Slotine, “Dynamical Pose Estimation,” in *Intl. Conf. on Computer Vision (ICCV)*, 2021, ([pdf](#)), ([video](#)), ([video](#))

## PROFESSIONAL ACTIVITIES

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### Talks and Presentations

- *Certifiable Outlier-Robust Geometric Perception: Robots that See through the Clutter with Confidence*
  - Department of Computer Science, Purdue University, March, 2022.
  - Department of Electrical and Computer Engineering, Princeton University, February, 2022.
  - Department of Electrical Engineering, Harvard University, February, 2022.
  - Department of Electrical and Systems Engineering, University of Pennsylvania, February, 2022.
  - Robotics Institute, University of Michigan, Ann Arbor, February, 2022. ([web](#))
  - Robotics Colloquium, University of Washington, January, 2022. ([web](#))
  - General Robotics, Automation, Sensing & Perception (GRASP) Lab, University of Pennsylvania, December, 2021. ([web](#)), ([video](#))
  - Cornell Robotics Seminar, September, 2021. ([web](#))
  - Department of Mechanical Engineering, University of Wisconsin-Madison, January, 2022.
  - College of Computing and Informatics, University of North Carolina Charlotte, October, 2021.
  - Hong Kong University of Science and Technology, October, 2021.
- *Self-supervised Geometric Perception*, [MatchLab](#), Imperial College London, May, 2021. ([slides](#))
- *Certifiable Outlier-Robust Machine Perception*
  - Guest Lecture, Robotics: Science and Systems (6.141J, 16.405J), Massachusetts Institute of Technology, May, 2021.
  - Guest Lecture, Visual Navigation for Autonomous Aerial Vehicles (VNA2V, AEROSP 740), University of Michigan, Ann Arbor, April, 2021.
- *A Fast Certifier for Large-Scale Degenerate SDPs in Outlier-Robust Machine Perception*, [MIT LIDS & Stats Tea](#), March, 2021.
- *Certifiably Robust Algorithms: From Global Optimization to Safer Perception*, [MIT Driverless](#), September, 2020. ([video](#))
- *Certifiably Robust Geometric Perception with Outliers*, RSS Workshop “Certifiable Robot Perception: from Global Optimization to Safer Robots”, July, 2020. ([slides](#)) ([video](#))
- *Certifiably Robust Geometric Perception with Outliers: From TEASER to Beyond*, [Marine Robotics Group](#), [SPARK Lab](#), MIT, June, 2020. ([video](#))
- *A Certifiably Optimal Solution for Robust Registration with Extreme Outlier Rates*, “Northeast Robotics Colloquium” (NERC), October, 2019. (6 selected out of 38 submissions) ([link](#)) ([slides](#)) ([poster](#))
- *Hands-on Tutorial on Global Optimization in Matlab*, ICCV Tutorial “Global Optimization for Geometric Understanding with Provable Guarantees”, November, 2019. ([link](#))

### Organizer for International Workshops and Tutorials

- *Global Optimization for Geometric Understanding with Provable Guarantees*, in conjunction with “International Conference on Computer Vision” (ICCV), 2019. ([link](#))
- *Certifiable Robot Perception: from Global Optimization to Safer Robots*, in conjunction with “Robotics: Science and Systems” (RSS), 2020. ([link](#))

### Reviewer for International Conferences and Journals

- *Journals*: IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI); IEEE Robotics and Automation Letters (RA-L); IEEE Transactions on Robotics (T-RO); International Journal of Robotics Research (IJRR); Journal of Mathematical Imaging and Vision; Autonomous Robots; Graphical Models; International Journal of Computer Vision (IJCV); Computational Optimization and Applications (COAP); Journal of Field Robotics; Transactions on Visualization and Computer Graphics (TVCG)
- *Conferences*: Robotics: Science and Systems (RSS); International Conference on Computer Vision (ICCV); International Conference on Robotics and Automation (ICRA); IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS); Learning for Dynamics & Control (L4DC); Conference on Computer Vision and Pattern Recognition (CVPR); Workshop on AI for Space (AI4Space); Conference on Neural Information Processing Systems (NeurIPS); International Conference on Learning Representations (ICLR)

## EXPERIENCES

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**Sensing, Perception, Autonomy, and Robot Kinetics (SPARK) Lab** 12/2018–Present  
*Ph.D. Candidate at LIDS (Advisor: Luca Carlone)* MIT, Cambridge, MA

- Developed the theoretical and computational foundations of certifiable outlier-robust geometric estimation in robot visual perception, based on a set of advanced machinery including robust estimation, semidefinite relaxation, and large-scale convex optimization

**Intel Intelligent Systems Lab, Intel** 5/2020–9/2020  
*Research Intern (Manager: Vladlen Koltun)* Intel, Santa Clara, CA

- Self-supervised geometric perception (*CVPR 2021 oral*)

**Device Realization and Computational Instrumentation Lab** 9/2015–11/2018  
*M.S. Candidate (Advisor: Brian W. Anthony)* MIT, Cambridge, MA

- Built a portable external mechanical vibration system, for Philips clinical low-cost shear wave elastography (*3 conference papers and 1 journal paper published, 2 patent applications filed*)

**Tesla, Inc.** 6/2017–9/2017  
*Advanced New Technology Integration Intern* Palo Alto, CA

- Modeled full-vehicle thermal-electrical dynamics including 28 sub-assemblies and 200+ devices in Matlab/Simulink for next-generation harness-free vehicle power and signal distribution

**Division of Intelligent and Biomechanical Systems** 9/2013–6/2015  
*Undergraduate Research Assistant* Tsinghua University, Beijing, China

- Pioneered in the study of the drinking strategy of honeybees and the flying strategy of beetles (*4 journal papers published*)

## TEACHING

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- **Guest lecturer**: *Robotics: Science and Systems (6.141J, 16.405J)*, Massachusetts Institute of Technology, May, 2021.
- **Guest lecturer**: *Visual Navigation for Autonomous Aerial Vehicles (VNA2V, AEROSP 740)*, University of Michigan, Ann Arbor, April, 2021.
- **Teaching assistant**: *Visual Navigation for Autonomous Vehicles (16.485)*, Massachusetts Institute of Technology, Fall 2020.
- **Instructor**: *Summer Camp in Robotics for Chinese Students*, Boston, 2018-2019.

## SERVICE

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- **Program Committee**, Robotics: Science and Systems (RSS) Pioneers, 2022.

- **Program Committee**, AAAI-22 Student Abstract and Poster Program, 2022.
- **LIDS & Stats Tea Talks Committee**, Massachusetts Institute of Technology, 2021 Spring.
- **Co-organizer and Co-chair of the 26th LIDS Student Conference**, Massachusetts Institute of Technology, 2020-2021. ([website](#))
- **Student volunteer of *Robotics Today – A Series of Technical Talks* seminar series**, streamed via web and twitter, 2020. ([website](#))
- **Executive board member of the Chinese Student and Scholar Association**, Massachusetts Institute of Technology, 2016-2018.
- **Outings Co-Chair of Sidney-Pacific Graduate Residence**, MIT, 2016-2017.

*Last update: February 3, 2022*