Dr. Cai Panpan

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I am a roboticist. I have been conducting active research in robotic planning under uncertainty, robot learning, and the integration of them. My vision is to develop robots that can combine reasoning and learning to seamlessly interact with large-scale, dynamic, and interactive environments and accomplish challenging tasks. Check this video for a 3-min introduction of my recent research.

Education

Nanyang Technological University **Singapore**
Doctor of Philosophy *2011.8–2016.7*
Research on robotic path planning, collision detection, and GPU computing.

PhD Thesis: *Massively Parallelized GA Based Optimal Path Planning for Single and Dual Crane Lifting in Complex Industrial Environments*

Zhejiang University **Hangzhou, China**
Bachelor's Degree in Mathematics (specialized on Information and Computing Science)
Top student selected into the ChuKoChen Honors College *2007.8–2011.6*
Trained on Mathematics, scientific computing, and Computer Aided Geometric Design (CAGD).

Professional Experience

Department of Computer Science, National University of Singapore **Singapore**
Postdoctoral research fellow (senior) *2017–now*

- Autonomous driving in dense urban traffics. How can a robot vehicle drive better than human in challenging environments where the traffic is dense and chaotic? My solution is to "think locally and learn globally". I proposed a crowd-driving algorithm, LeTS-Drive (Paper, Talk), that integrates POMDP planning and reinforcement learning in a close-loop to tackle autonomous driving in crowded, chaotic urban traffic.
- Online planning under uncertainty. Robots in the real-world have to hedge against uncertainties, but the corresponding planning problem can be computationally intractable. My solution is a parallel belief tree search algorithm, HyP-DESPOT (Paper, Talk), that combines CPU and GPU parallelization to speedup planning under uncertainty by hundreds of times and successfully achieve real-time performance in large-scale problems.
- Modeling and predicting traffic agents. Modeling and predicting other agents are crucial for robots to operate in shared environments such as urban traffic. I have developed two traffic motion models, PORCA (Paper, Video) and GAMMA (Paper, Video), for autonomous driving in challenging urban environments. They have been plugged into planning algorithms to build interaction-aware driving systems that improve safety and efficiency.
- Urban traffic simulation. Simulators provide a rich source of interactive driving data to facilitate the development of driving algorithms. However, good simulators for driving among crowded environments are still lacking. I thus developed an open-source crowd-driving simulator, SUMMIT (Paper, Talk), that simulates massive traffic crowds in real-world urban maps to boost up research and development in the challenging crowd-driving domain.

School of Mechanical and Aerospace Engineering, Nanyang Technological University **Singapore**
PhD student *2011–2016*

- Real-time collision detection in complex environments. Collision detection is not only a computer-graphic problem, but also an important and expensive subroutine of robot planning. I proposed to use image-based representation for the environment and GPU-based massive parallelization to speedup collision detection. The resulting algorithm achieves real-time collision detection on complex industrial environments consisting of millions of polygons.
- Parallel path planning for single- and cooperative-crane lifting. Path planning in complex environments is computationally hard. The cooperation of two heavy-lifting cranes and the suspended lifting target further add to the difficulties. I proposed to use Genetic Algorithms for optimal planning and integrate it with massively parallelized collision detection to enable near real-time lift planning in complex industrial environments.

Professional Services

- Main organizer, RSS 2021 workshop on Integrating Planning and Learning.
- Program committee member, Robotics: Science & Systems (RSS), 2020.
- Program committee member, Conference on Robot Learning (CORL), 2019.
- Program committee member, CS research week 2019, School of Computing, NUS.

- Reviewers for top robotics and AI conferences (RSS, ICRA, CORL, IROS, ACC, IJCAI) and top-tier journals (IJRR, TRO, RAL, AURO).
- Speaker, NUS SOC research Workshop in Vietnam, 2019.

Teaching

- Co-lecturing, Module CS4278/CS5478 "Intelligent Robots: Algorithms and Systems", 2021, Lecture 11 & 12, NUS.
- Co-lecturing, Module CS6244 "Robot Motion Planning & Control", Semester 1, 2017/2018, Lecture 3, NUS.
- Teaching assistance, Project P3.6 "Vibration Testing of Multiple DOF Systems" for AY 2015/16, S1 & S2, NTU.

Publications

Conference papers:

- Y Lee and P Cai, and D Hsu. MAGIC: Learning Macro-Actions for Online POMDP Planning using Generator-Critic. Robotics: Science & Systems (RSS), 2021.
- P Cai, Y Lee, Y Luo, D Hsu. SUMMIT: A Simulator for Urban Driving in Massive Mixed Traffic. International Conference on Robotics and Automation (ICRA), 2020.
- P Cai, Y Luo, A Saxena, D Hsu, WS Lee. LeTS-Drive: Driving in a Crowd by Learning from Tree Search. Robotics: Science & Systems (RSS), 2019.
- M Meghjani*, Y Luo, Q H Ho, P Cai, S Verma, D Rus, D Hsu. Context and Intention Aware Planning for Urban Driving. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2019.
- P. Cai, Y. Luo, D. Hsu, and W.S. Lee. HyP-DESPOT: A Hybrid Parallel Algorithm for Online Planning under Uncertainty. Robotics: Science & Systems (RSS), 2018.
- P. Cai, Y. Cai, I. Chandrasekaran, and J. Zheng, "A GPU-enabled parallel genetic algorithm for path planning", 2013 Symposium on GPU Computing and Applications, Oct 2013, Singapore. (Best Paper)

Journal papers::

- P Cai and D Hsu. Closing the Planning-Learning Loop with Application to Autonomous Driving in a Crowd . Submitted to the IEEE Transaction on Robotics (T-RO), 2021.
- (Equal-contribution first author, corresponding author) Y Luo, P Cai, Y Lee, and D Hsu. SUMMIT: Simulating Urban Driving in Massive Mixed Traffic. Submitted to IEEE Robotics and Automation Letters (RAL), 2021.
- P. Cai, Y. Luo, D. Hsu, and W.S. Lee. HyP-DESPOT: A Hybrid Parallel Algorithm for Online Planning under Uncertainty. International Journal of Robotics Research (IJRR), 38 (2-3), pp.162-181, 2020.
- Y.F. Luo, P.P. Cai, A. Bera, D. Hsu, W.S. Lee, and D. Manocha. PORCA: Modeling and planning for autonomous driving among many pedestrians. In IEEE Robotics Automation Letters (RAL), vol. 3, no. 4, pp. 3418-3425, 2018.
- P. Cai, Y. Cai, I. Chandrasekaran, and J. Zheng "Automatic Path Planning for Dual-Crane Lifting in Complex Environments Using a Prioritized Multi-objective PGA", IEEE Transactions on Industrial Informatics (TII), 14(3), 829-845, 2017.
- P. Cai, Y. Cai, I. Chandrasekaran, and J. Zheng. "Parallel GA based automatic crane lifting path planning in complex environments", Automation in Construction (AIC), Volume 62, Pages 133-147, 2016.

Preprint papers:

- Y Luo, P Cai, D Hsu, and WS Lee. GAMMA: A General Agent Motion Prediction Model for Autonomous Driving. arXiv:1906.01566, 2019.

Book chapters::

- P. Cai, Y. Cai, I. Chandrasekaran, and J. Zheng, "A GPU-enabled parallel genetic algorithm for path planning of robotic operators", in Y. Cai and Simon See (eds.), GPU Computing and Applications, pp. 1-13, Springer, 2015.
- P. Cai, C. Indhumathi, Y. Cai, J. Zheng, Y. Gong, T. Lim, and P. Wong, "Collision detection using axis aligned bounding boxes", in Simulations, Serious Games and Their Applications (Y. Cai and S. L. Goei, eds.), Gaming, Media and Social Effects, pp. 1-14, Springer Singapore, 2014.