Changhao Wang | Curriculum Vitae

2103 Etcheverry Hall, Berkeley, California, 94720

changhaowang@berkeley.edu • changhaowang.github.io

I am a fifth-year Ph.D. student at UC Berkeley advised by Prof. Masayoshi Tomizuka. My research interest lies in the interdisciplinary combination of optimization, control, and reinforcement learning with applications to dexterous manipulation, contact-rich manipulation, and motion planning. I like to develop algorithms that can work robustly on real robots.

Education Background

- **University of California, Berkeley** — **Berkeley, CA**
  Ph.D. Major: Controls, Minor: Optimization and Robotics — *2018.8–2023.12 (expected)*
  Mechanical Engineering Department, **GPA:4.0/4.0**
- **Shanghai Jiao Tong University** — **Shanghai, CHN**
  B.S. Major: Mechanical Engineering, School of Mechanical Engineering. — *2014.9–2018.7*

Professional Experience

- **Honda Research Institute** — **San Jose, CA**
  Research Intern. — *2023.5–2023.8*
  1. Explored deep reinforcement learning and model-based methods for dexterous manipulation
  2. Utilized a teacher-student model structure for understanding tactile signal for in-hand manipulation
  3. Proposed an online residual policy update for bridging the sim-to-real gap
  4. Experimented the algorithm on Allegro Hand with Uskin tactile sensor for tool manipulation
- **Everyday Robots, (Google) X, the Moonshot Factory** — **Mountain View, CA**
  Resident. Advisor: Jeffrey Bingham — *2022.5–2022.8*
  1. Explored various compliance robot control algorithms for contact rich manipulation
  2. Proposed a robust variation of impedance/admittance control that do not require force/torque sensing
  3. Experimented the algorithm on contact rich manipulation tasks, such as table wiping and door opening.
- **(Google) X, the Moonshot Factory** — **Mountain View, CA**
  Robotics Research Intern. — *2020.5–2020.8*
  1. Proposed an efficient distributed formulation for online trajectory optimization
  2. Implemented the algorithm with state-of-the-art collision checker and tested it in various simulation benchmarks
  3. Experimented the proposed algorithm on multiple motion planning scenarios
- **FANUC Advanced Research Lab** — **Union City, CA**
  Robotics Research Intern — *2019.6–2019.8*
  1. Proposed a next generation collision avoidance algorithm with nonlinear programming
  2. Proved the proposed method is able to guarantee continuous trajectory safety in theory
  3. Simulated the robot motion in RoboGUIDE and did various real world experiments with FANUC robots.

Selected Research Experiences

- **Learning Dexterous Manipulation Policy for In-hand Manipulation** — **Honda Research Institute**
  2023.6–Current
  1. Utilized deep reinforcement learning to learn from a model-based method to warm start the training
  2. Utilized a teacher-student model structure for understanding tactile signal for in-hand manipulation
  3. Proposed an online residual policy update for bridging the sim-to-real gap
  4. Experimented the algorithm on Allegro Hand with Uskin tactile sensor for tool manipulation

- **Learning Robust Contact-rich Manipulation Skills** **UC Berkeley**
  Advisor: Prof. Masayoshi Tomizuka *2023.1–Current*
  1. Utilized offline reinforcement learning to learn various contact manipulation skills, such as assembly, door opening, and table wiping
  2. Formulated a model predictive controller with the learned model to optimize the robot movement
  3. Demonstrate the effectiveness of the method through comparative simulation and experiment results
- **Offline-Online Learning for Cable Manipulation with Graph Neural Networks** **UC Berkeley**
  Advisor: Prof. Masayoshi Tomizuka *2021.5–2022.2*
  1. Combined the offline GNN dynamics with an online residual model for accurate model learning
  2. Proposed an test time gain optimization methods for sim-to-real transfer
  3. Demonstrate the effectiveness of the method through comparative simulation and experiment results
- **Safe Online Gain Optimization for Variable Impedance Control** **UC Berkeley**
  Advisor: Prof. Masayoshi Tomizuka *2021.1–2022.1*
  1. Provided a new perspective to understand the relationship be- tween impedance gains and the robot states.
  2. Proposed efficient online gain optimization framework for variable impedance control.
  3. Incorporated collision avoidance for variable impedance control.
- **Trajectory Splitting Optimization for Efficient Online Motion Planning** **UC Berkeley**
  Advisor: Prof. Masayoshi Tomizuka *2020.9–2021.1*
  1. Proposed a distributed trajectory planning framework for online motion planning
  2. Integrated the proposed framework with the state-of-the-art collision checker algorithm
  3. Tested the proposed algorithm in various benchmark to demonstrate the effectiveness
- **Robotic Bottle Filpping and Landing with TRPO and Adaptive MPC** **UC Berkeley**
  Advisor: Prof. Pieter Abbeel and Prof. Masayoshi Tomizuka *2019.9–Present*
  1. Utilized Trust Region Policy Optimization (TRPO) for bottle flipping with a FANUC LRMate 200 iD robot
  2. Trained a LSTM for bottle trajectory prediction and designed an adaptive MPC controller to stabilize the bottle
  3. Validated the framework in the Pybullet Simulator (Check the video here: https://changhaowang.github.io)
- **Worst State Trajectory Optimization (WSTO) for Robotic Motion Planning** **UC Berkeley**
  Advisor: Prof. Masayoshi Tomizuka *2019.3–2019.6*
  1. Proposed a novel trajectory optimization framework that considers in-between states collision efficiently
  2. Introduced a state parameterization method to represent every state on a continuous trajectory by one parameter
  3. Proved the proposed WSTO framework is robust under various scenarios with a FANUC M20iA robot
- **Deformable Object Manipulation with Imitation Learning** **UC Berkeley**
  Advisor: Prof. Masayoshi Tomizuka *2017.6–2017.9*
  1. Designed a robust real-time tracker that estimates the state of a deformable object under occlusions
  2. Applied an imitation learning-based method on robotic manipulation tasks (rope knotting, and cloth folding)
  3. Developed state recognition, trajectory warping, and failure detection algorithms with non-rigid point set registration to improve the efficiency and robustness of deformable object manipulation
  4. Proposed a tangent space non-rigid registration method to prevent objects from being overstretched.

Awards

1. **ME Department Fellowship** (UC Berkeley) 2023
2. **Chin Leung Shui Chun Fellowship** (UC Berkeley) 2020
3. **Graduate Division Block Grant Award** (UC Berkeley) 2020
4. **The First Prize in Shanghai in the China Undergraduate Mathematical Contest in Modelling** 2016
5. **The Second Prize in the China Undergraduate Mathematical Contest in Modelling** (Top 1%) 2016

Publications and Patents

[1] **Changhao Wang***, Xiang Zhang*, Linfeng Sun, Zheng Wu, Xinghao Zhu, and Masayoshi Tomizuka. Efficient sim-to-real transfer of contact-rich manipulation skills with online admittance residual learning. *2023 Conference*

on Robot Learning (CORL), Accepted, 2023.

[2] Zheng Wu, Yichen Xie, Wenzhao Lian, **Changhao** Wang, Yanjiang Guo, Jianyu Chen, Stefan Schaal, and Masayoshi Tomizuka. Zero-shot policy transfer with disentangled task representation of meta-reinforcement learning. *2023 International Conference on Robotics and Automation (ICRA)*, 2023.

[3] Mingrui Yu, Kangchen Lv, **Changhao Wang**, Masayoshi Tomizuka, and Xiang Li. A coarse-to-fine framework for dual-arm manipulation of deformable linear objects with whole-body obstacle avoidance. *2023 International Conference on Robotics and Automation (ICRA)*, 2023.

[4] **Changhao Wang**, Yuyou Zhang, Xiang Zhang, Zheng Wu, Xinghao Zhu, Shiyu Jin, Te Tang, and Masayoshi Tomizuka. Offline-online learning of deformation model for cable manipulation with graph neural networks. *IEEE Robotics and Automation Letters*, 7(2):5544–5551, 2022.

[5] **Changhao Wang**, Xiang Zhang, Zhian Kuang, and Masayoshi Tomizuka. Safe online gain optimization for cartesian space variable impedance control. In *2022 IEEE 18th International Conference on Automation Science and Engineering (CASE)*, pages 751–757. IEEE, 2022.

[6] **Changhao Wang**, Hsien-Chung Lin, Shiyu Jin, Xinghao Zhu, Liting Sun, and Masayoshi Tomizuka. Bpomp: A bilevel path optimization formulation for motion planning. In *2022 American Control Conference (ACC)*, pages 1891–1897. IEEE, 2022.

[7] Xiang Zhang, Shiyu Jin, **Changhao Wang**, Xinghao Zhu, and Masayoshi Tomizuka. Learning insertion primitives with discrete-continuous hybrid action space for robotic assembly tasks. In *2022 International Conference on Robotics and Automation (ICRA)*, pages 9881–9887. IEEE, 2022.

[8] Shiyu Jin, Wenzhao Lian, **Changhao Wang**, Masayoshi Tomizuka, and Stefan Schaal. Robotic cable routing with spatial representation. *IEEE Robotics and Automation Letters*, 7(2):5687–5694, 2022.

[9] **Changhao Wang**, Jeffrey Bingham, and Masayoshi Tomizuka. Trajectory splitting: A distributed formulation for collision avoiding trajectory optimization. In *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2021.

[10] **Changhao Wang***, Shiyu Jin*, and Masayoshi Tomizuka. Robust deformation model approximation for cable manipulation. In *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2019.

[11] **Changhao Wang***, Te Tang*, and Masayoshi Tomizuka. A framework for manipulating deformable linear objects by coherent point drift. *IEEE Robotics and Automation Letters*, 3(4):3426–3433, 2018.

[12] Yu Sun, Wyatt L Ubellacker, Wen-Loong Ma, Xiang Zhang, **Changhao Wang**, Noel V Csomay-Shanklin, Masayoshi Tomizuka, Koushil Sreenath, and Aaron D Ames. Online learning of unknown dynamics for model-based controllers in legged locomotion. *IEEE Robotics and Automation Letters*, 6(4):8442–8449, 2021.

[13] Shiyu Jin, Xinghao Zhu, **Changhao Wang**, and Masayoshi Tomizuka. Contact pose identification for peg-in-hole assembly under uncertainties. In *2020 American Control Conference (ACC)*, 2020.

[14] Shiyu Jin*, **Changhao Wang***, Xinghao Zhu*, Te Tang, and Masayoshi Tomizuka. Real-time state estimation of deformable objects with dynamical simulation. In *Workshop on Robotic Manipulation of Deformable Objects*, 2020.

[15] Xinghao Zhu, Yongxiang Fan, Shiyu Jin, **Changhao Wang**, and Masayoshi Tomizuka. Why does robotic dexterous hand grasp fail. In *Workshop Why robots fail to grasp, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2020.