Changhao Wang | Curriculum Vitae

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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 robotics, optimization, reinforcement learning and control theories with applications to robotic manipulation, motion planning, and robot skill learning.

Education Background

University of California, Berkeley | **Berkeley, CA**
Ph.D. Major: Controls, Minor: Artificial Intelligence and Robotics | *2018.8–2023.6 (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

Everyday Robots, (Google) X, the Moonshot Factory | **Mountain View, CA**
Resident. Advisor: Jeffrey Bingham | *2022.5–2022.8*

1. Explored compliance robot control algorithms called torque saturation for contact rich manipulation
2. 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

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. 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

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

Publications and Patents

[1] **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.

[2] **Changhao Wang***, Zhian Kuang*, Xiang Zhang*, and Masayoshi Tomizuka. Safe ongo-vic: Safe online gain optimization for variable impedance control. In *2022 IEEE international conference on automation science and engineering (CASE)*. IEEE, Accepted.

[3] **Changhao Wang** and Masayoshi Tomizuka. Bpomp: A bilevel path optimization formulation for motion planning. In *2022 American Control Conference (ACC)*, Accepted.

[4] **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.

[5] **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.

[6] **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.

[7] 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.

[8] 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.

[9] 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.

[10] 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.

[11] 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.

[12] 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.