Tao Pang

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I am a roboticist at the Boston Dynamics AI Institute (BDAII). Prior to BDAII, I did my PhD in robotics at MIT, advised by Prof. Russ Tedrake. I'm interested in designing practical, interpretable and effective planning and control algorithms for contact-rich robotic manipulation.

Education

- **Massachusetts Institute of Technology** 09/2016 - 01/2023
  PhD in Mechanical Engineering.
  - Thesis: Planning, Sensing, and Control for Contact-rich Robotic Manipulation with Quasi-static Contact Models.
  - Advisor: Prof. Russ Tedrake.
- **National University of Singapore** 08/2014 - 05/2016
  M.Eng., Electrical and Computer Engineering.
  - Thesis: Design, Prototyping and Autonomous Control of Gasoline-engine Variable-pitch Quadcopter.
  - Advisor: Prof. Ben M. Chen.
- **National University of Singapore** 08/2008 - 05/2012
  B.Eng (First Class Honors), Mechanical Engineering.
  - GPA: 4.89/5, with second major in mathematics.
  - Thesis: a CUDA-based Conjugate Gradient Solver for Finite Element Analysis.
  - Advisor: Prof. LIM Kian Meng.

Research Experience

- **Research Scientist** 02/2023 - Present
  Boston Dynamics AI Institute.
  - Enabling contact-rich manipulation capabilities for robots.
- **Research Assistant** 09/2016 - 01/2023
  Robot Locomotion Group, MIT CSAIL.
  - Developed a model-based contact-rich planning algorithm which can generate dexterous manipulation plans for a 16DOF anthromorphic hand in under 1 minute of wall-clock time. We identified smoothing as the effect of sampling, which is ubiquitous in reinforcement learning (RL), and sped up our method by the analytical smoothing of non-smooth contact dynamics without using samples.
  - Developed a convex, differentiable quasi-dynamic rigid body simulator, which can simulate contact-rich scenarios with a step size two orders of magnitude larger than second-order dynamics.
  - Designed and implemented a joint-torque-based contact force estimation and control pipeline for the Kuka iiwa arm. The controller would keep an egg intact if the arm accidentally ran into it.
  - Led the development of RobotPlanRunner, a middleware between research code and trajectory execution on real robots. The repository is under CI and used by multiple research projects in our lab.
- **Associate Scientist** 04/2013 - 08/2016
  Unmanned Systems Research Group, National University of Singapore.
  - Designed and built a 10kg gasoline-powered variable-pitch quadrotor which can remain airborne for up to 3 hours.
  - Provided mechanical design feedback and assistance to various projects in the group.
- **Summer Research Undergraduate Fellowship (SURF).** 05/2010 - 08/2010
  California Institute of Technology.
  - Designed and implemented a path planning algorithm for the Axel robot, a tethered Mars rover prototype.
  - Advisor: Prof. Joel W. Burdick.

Preprints

- **Global Planning for Contact-Rich Manipulation via Local Smoothing of Quasi-dynamic Contact Models** [pdf] 2022
  T. Pang, H.J.T. Suh*, L. Yang, R. Tedrake*
  Submitted to IEEE Transactions on Robotics (TR-O).

Journal Publications

- **Bundled Gradients through Contact via Randomized Smoothing** [pdf] 2022
  H.J.T. Suh, T. Pang*, R. Tedrake*
  IEEE Robotics and Automation Letters (RA-L).

Selected Conference Publications

- **SEED: Series Elastic End Effectors in 6D for Visuotactile Tool Use** [pdf] 2022
  H.J.T. Suh, N. Kuppuswamy, T. Pang, P. Mitiguy, A. Alspach, R. Tedrake
  IEEE International Conference on Intelligent Robots and Systems (IROS).
- **Easing Reliance on Collision-free Planning with Contact-aware Control** [pdf] 2022
  T. Pang, R. Tedrake
  IEEE International Conference on Robotics and Automation (ICRA).
- **A Convex Quasistatic Time-stepping Scheme for Rigid Multibody Systems with Contact and Friction** [pdf] 2021
  T. Pang, R. Tedrake
  IEEE International Conference on Robotics and Automation (ICRA).
- **Identifying External Contacts from Joint Torque Measurements on Serial Robotic Arms and Its Limitations** [pdf] 2021
  T. Pang, J. Umenberger, R. Tedrake
  IEEE International Conference on Robotics and Automation (ICRA).
- **A Robust Time-Stepping Scheme for Quasistatic Rigid Multibody Systems** [pdf] 2018
  T. Pang, R. Tedrake
  IEEE International Conference on Intelligent Robots and Systems (IROS).
- **Design and Implementation of a Variable-pitch Long-endurance Gasoline-engine Quadrotor** [pdf] 2016
  T. Pang, F. Lin, K. Peng and B.M. Chen
  IEEE International Conference on Control and Automation (ICCA).

Teaching Experience

- **Teaching Assistant** Fall 2018 & 2019
  First & second offerings of MIT 6.800/6.843, Robotic Manipulation.
  - Designed from scratch programming problem sets for basic topics in robotics, including kinematics, point cloud registration, force control and sampling-based motion planning.
  - Designed and supervised robot labs where students are asked to put a rubber brick inside a closed cabinet with the Kuka iiwa robot arm.

Awards & Honors

- **First Prize.** 2014
  International Micro Air Vehicle (IMAV) Competition, Delft, Netherlands.
  - 1^{st} place out of 12 teams from 7 countries.
  - In charge of mechanical design of the quadrotor and on-board components such as camera gimbals.
- **Overall Champion Award** (Gold), **Best Performance Award** (Gold), **Most Creative Award** (Bronze). 2014
  Singapore Amazing Flying Machine Competition, Singapore.
  - Category E: Unconventional Aircraft.
  - Most renowned aerial robot competition in Singapore.
  - Designed the mechanical structure of a tail-sitter aircraft capable of transition between VTOL and fixed-wing

modes.

- **First Place in Grand Final**. 2013
  Second AVIC Cup - International UAV Innovation Grand Prix, Beijing, China.
  - The task was to transport buckets between moving platforms using drones.
  - Competed with teams from Tsinghua University, China Academy Sciences, Beijing University of Aeronautics and Astronautics, Nanjing University of Aeronautics and Astronautics etc.
  - In charge of mechanical design of the bucket grabbing payload.
- **Lee Kuan Yew Gold Medal, IES Gold Medal, Exxonmobil Medal**. 2012
  National University of Singapore.
  - Student with the highest GPA in Mechanical Engineering during his period of study.
- **Lee Kwok Hong Memorial Medal and Prize**. 2012
  National University of Singapore.
  - Best student in the areas of dynamics and computational mechanics.
- **Dean's List** $\times 7$. 2008-2012
  National University of Singapore.
  - Award for having top 5% grades in the Department of Mechanical Engineering
  - Awarded for every semester during undergraduate study at NUS.
- **Undergraduate Scholarship**. 2008-2012
  National University of Singapore.
  - Full undergraduate tuition and stipend.

Skills

- **C++:** Advanced
- **Python:** Advanced
- **MIT Drake:** Advanced
- **ROS:** Advanced
- **SolidWorks:** Advanced
- **MATLAB/Simulink:** Advanced
- **Pytorch:** Intermediate
- **Julia:** Intermediate