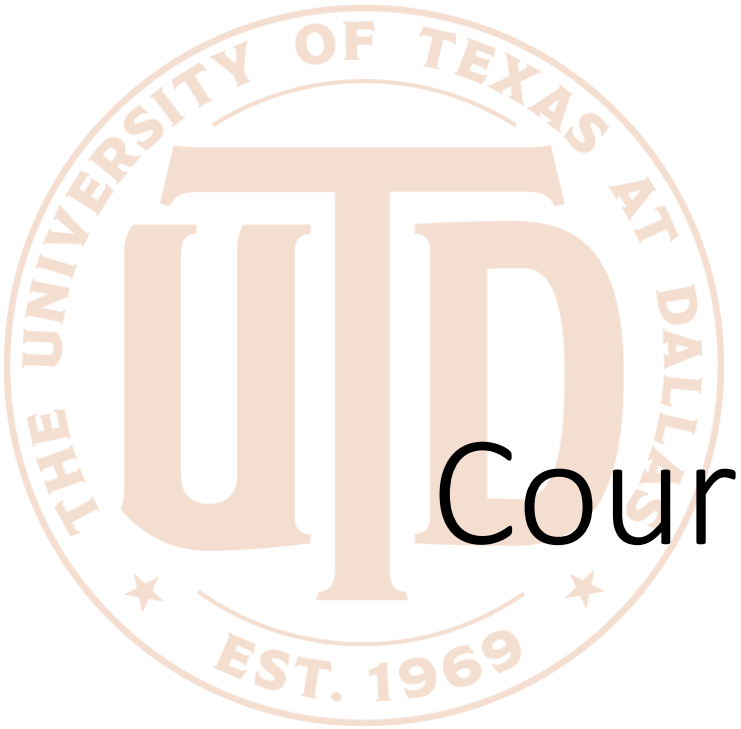


Course Project Description

CS 6301 Special Topics: Introduction to Robot Manipulation and Navigation

Professor Yu Xiang

The University of Texas at Dallas

Course Project

- Team Project (45%)
  - 2 - 3 students for a project
  - Project proposal (5%)
  - Project mid-term report (10%)
  - Project presentation (15%)
  - Project final report (15%)

Course Project Tracks

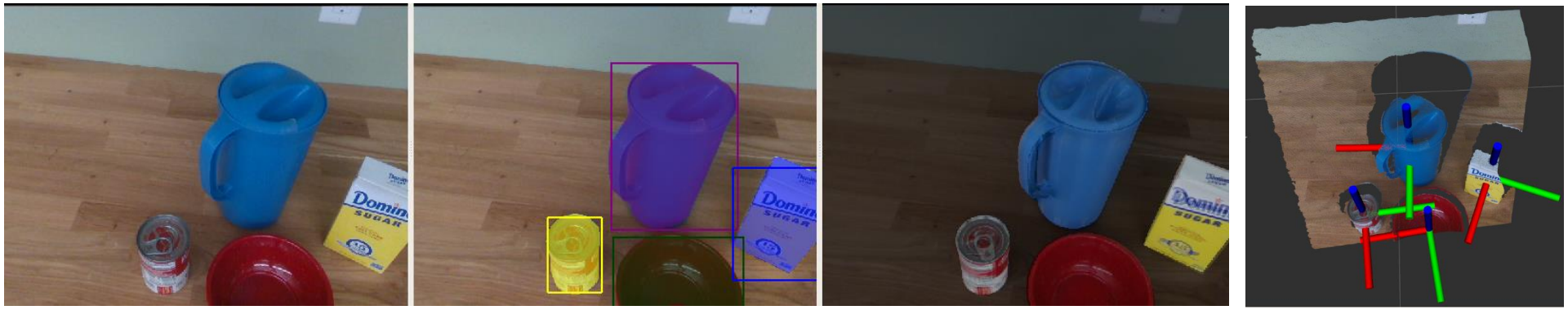
- Research-oriented
  - Proposal a new idea in robotics that has not been explored before
  - Implement the new idea and conduct experiments to verify it
- Application-oriented
  - Apply an existing algorithm or method to a new problem or a new application
  - E.g., if a method is proposed for domain A, explore applying it to a different domain
- Implementation-oriented
  - Select an existing algorithm or method, implement it and conduct experiments to verify the implementation
  - Cannot just use open-source code and run experiments with it

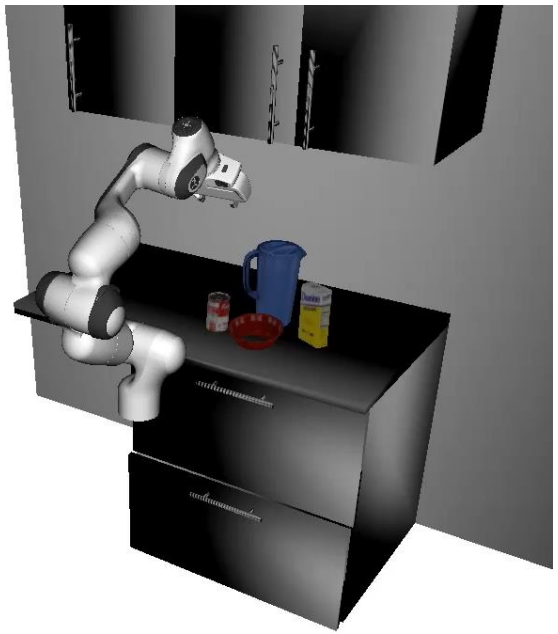
Mandatory Requirements

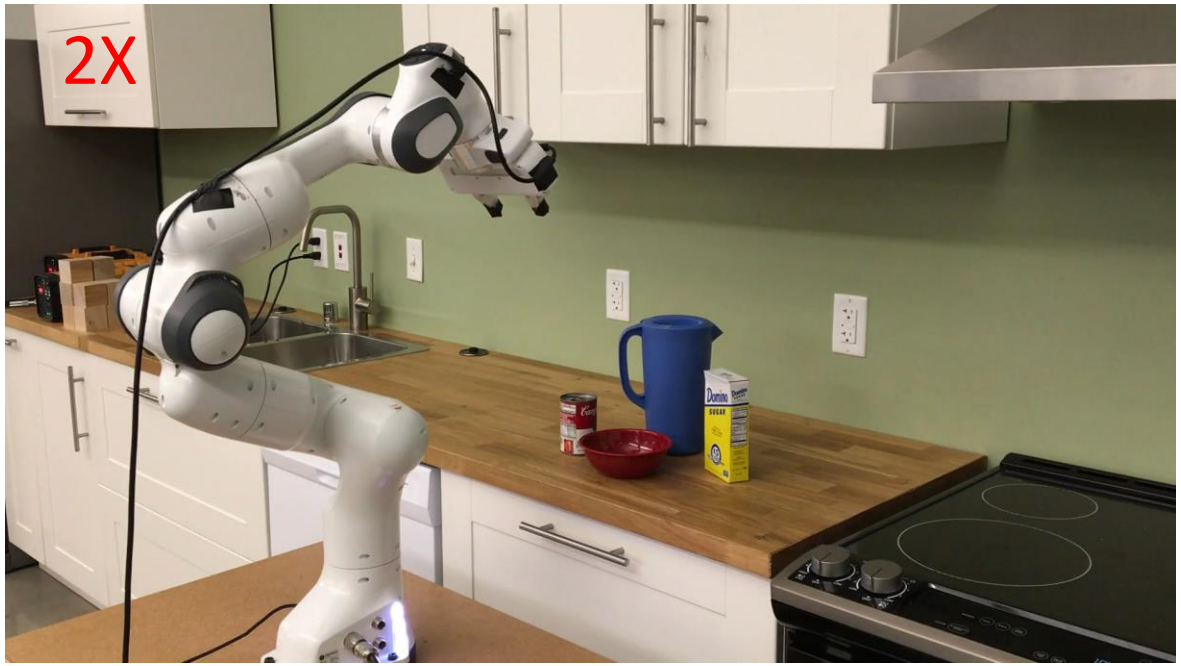
- The project needs to have a robot

- The project needs to have robot manipulation

Topic: Model-based Grasping

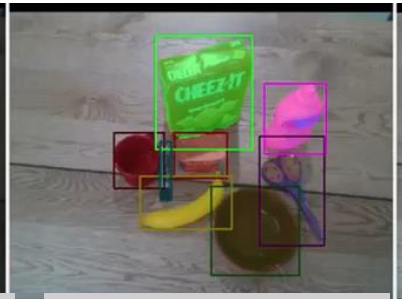






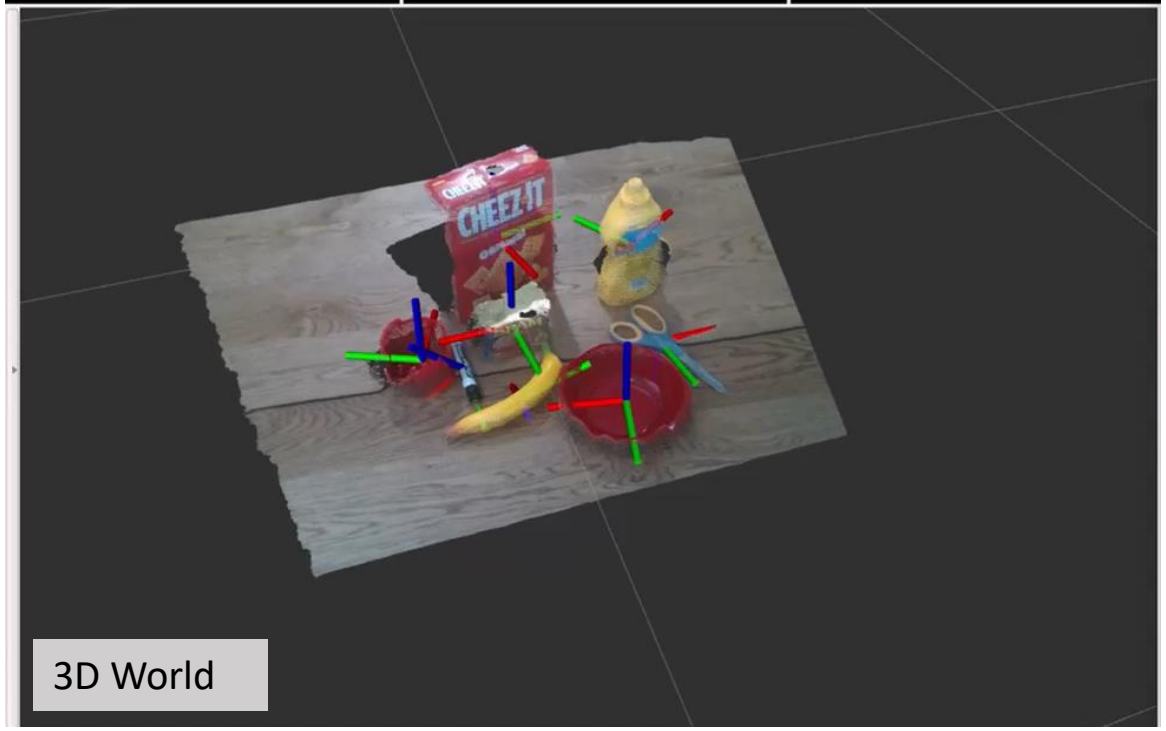
Topic: 6D Object Pose-based Grasping

Overlay of 3D Models



2D Segmentation

Input Image



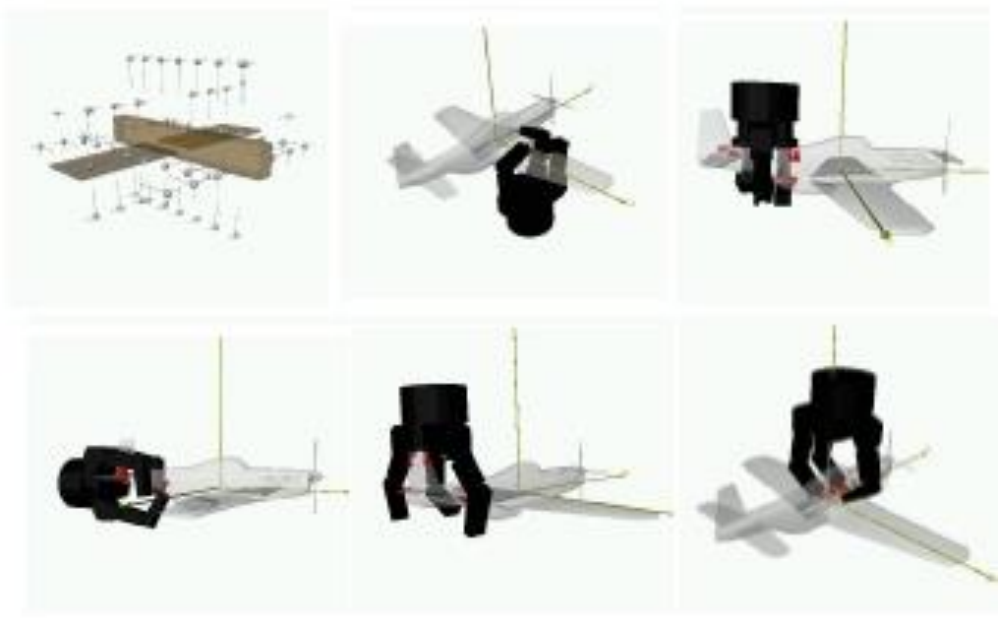
3D World

3D models

Self-supervised 6D Object Pose Estimation for Robot Manipulation. Deng et al., ICRA'20

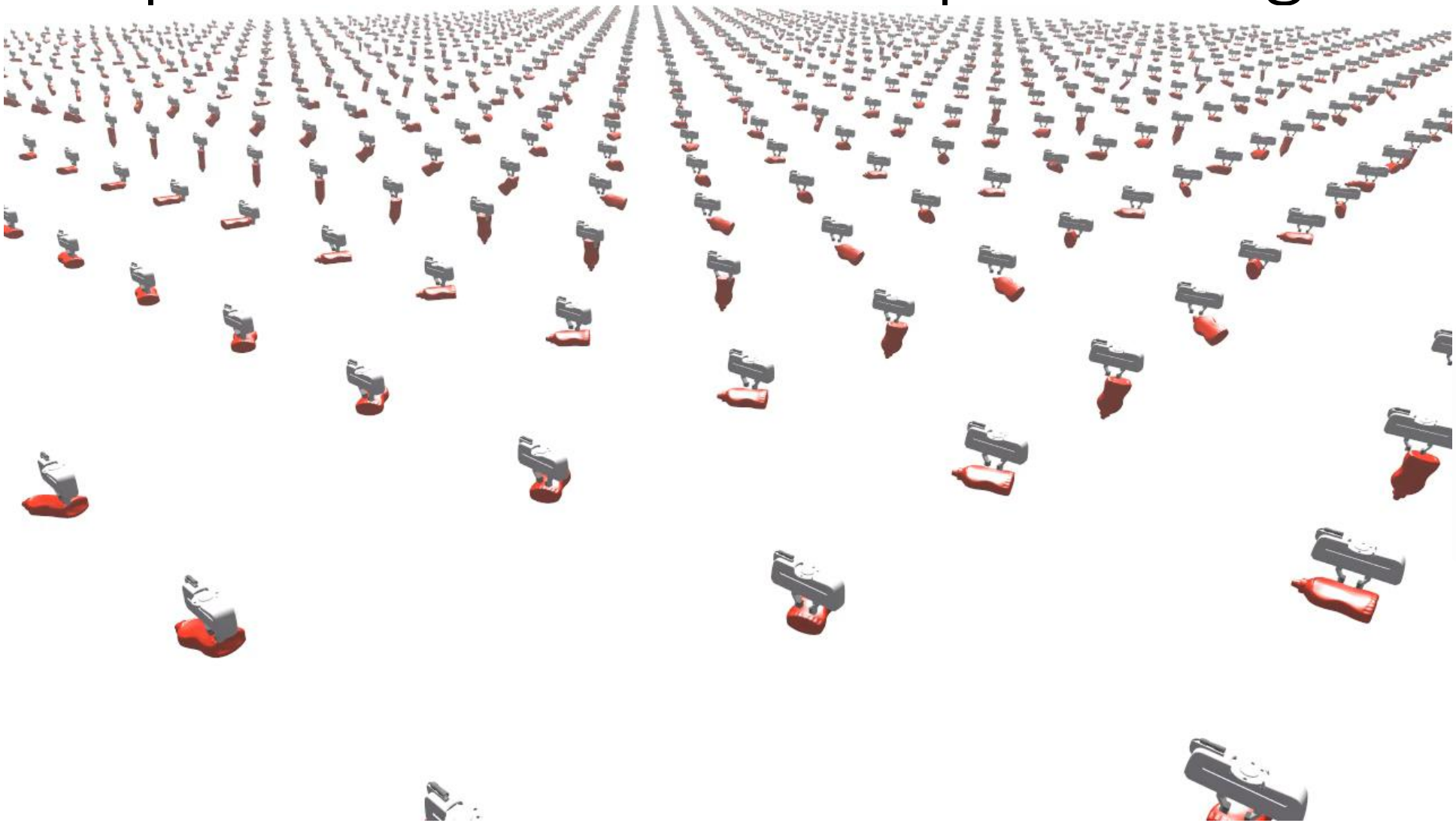
https://arxiv.org/abs/1909.10159

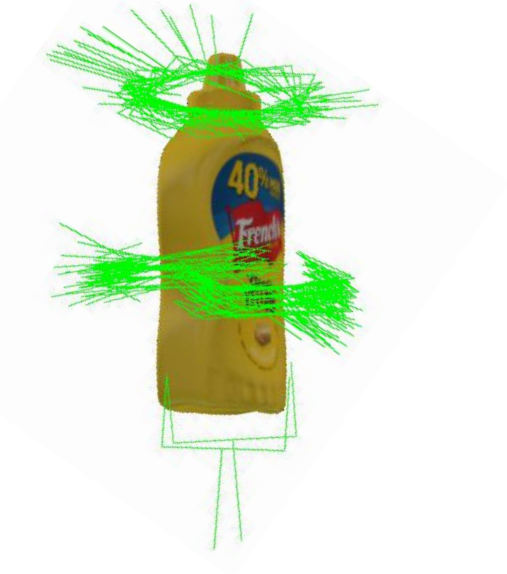
Topic: Model-based Grasp Planning



Graspit! https://graspit-simulator.github.io/

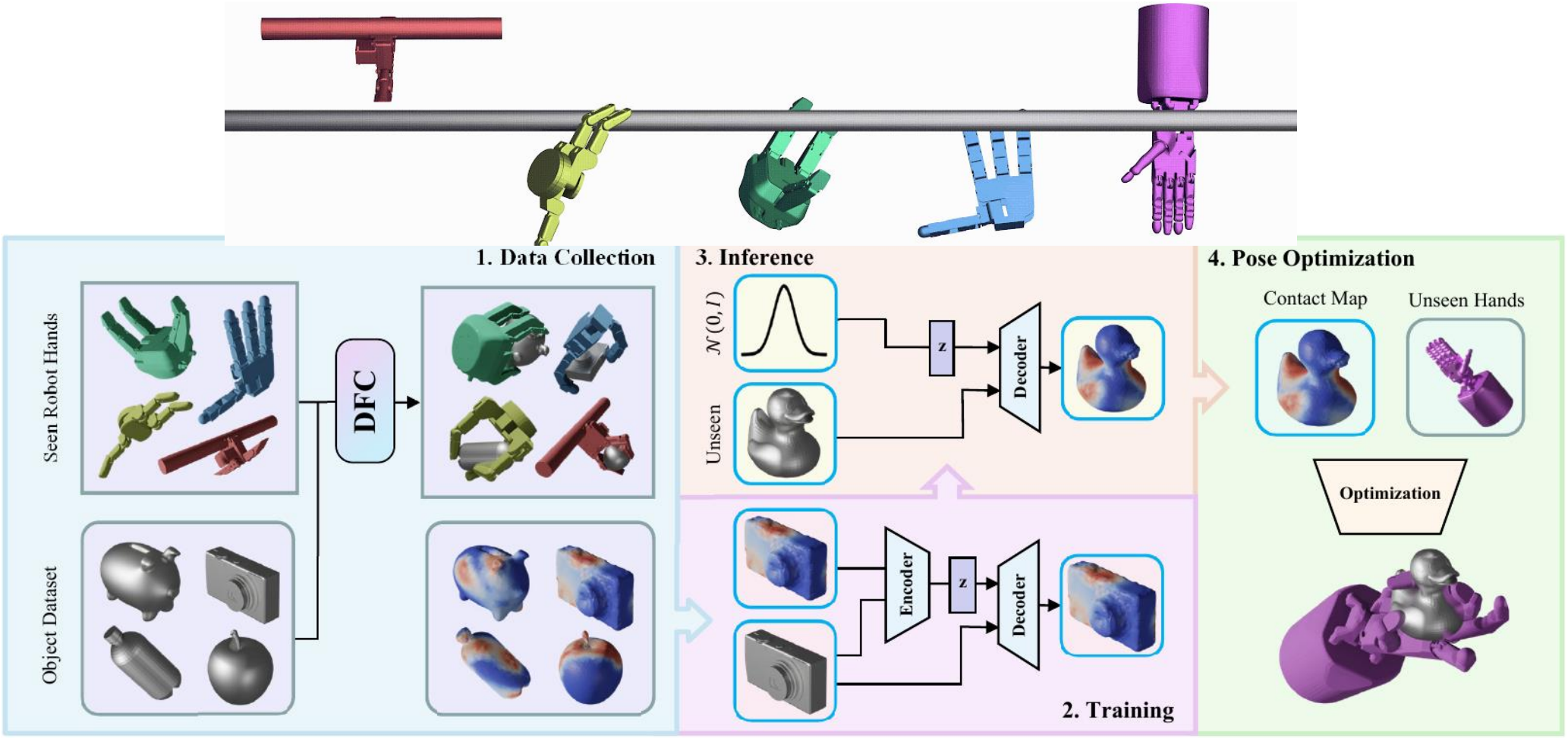
Topic: Model-based Grasp Planning





Eppner-Mousavian-Fox, ISRR'19

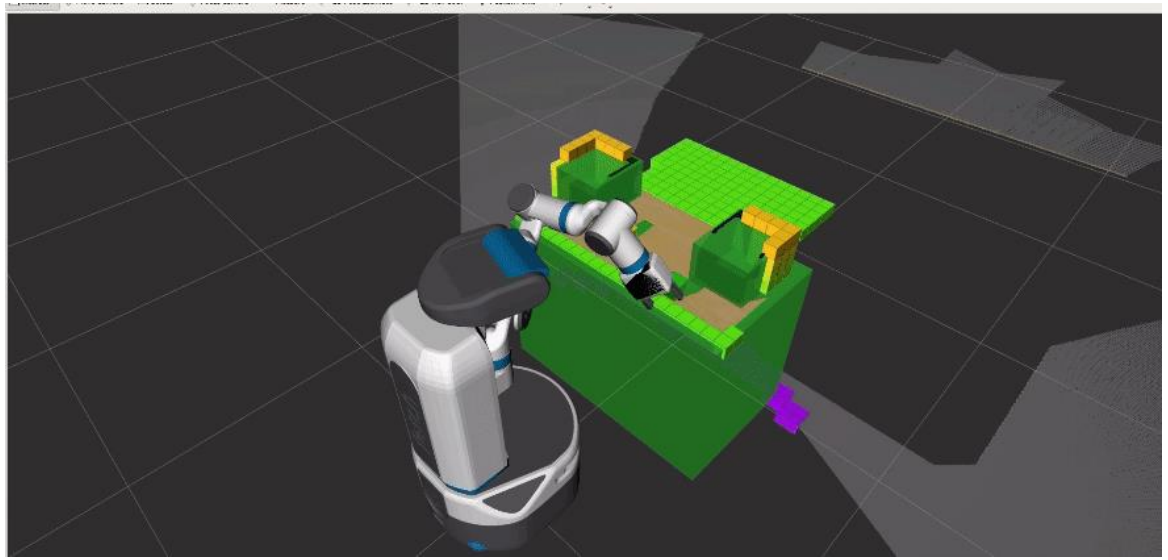
Topic: Model-based Grasp Planning

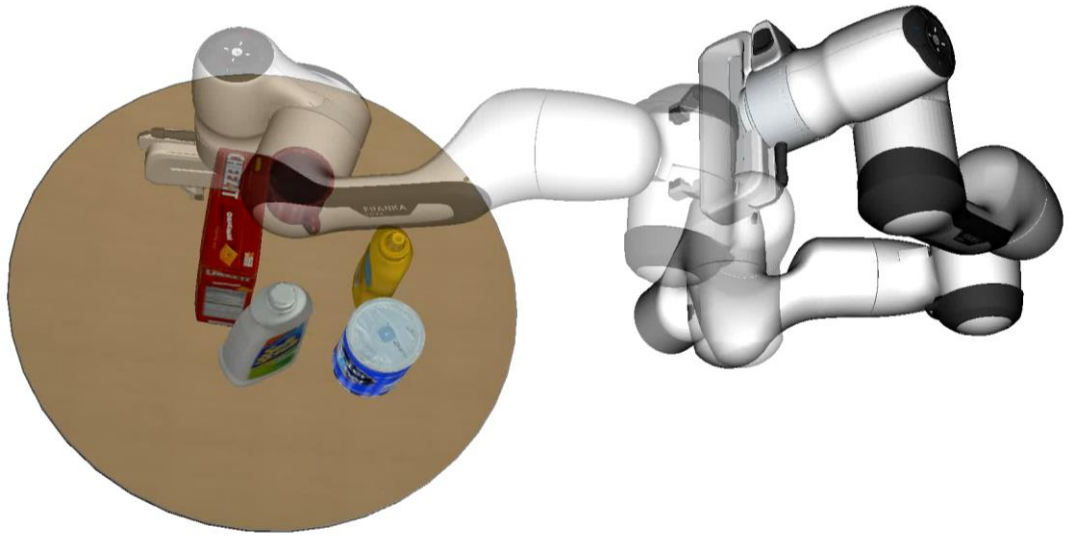


GenDexGrasp, Li et al., ICRA, 2023

https://github.com/tengyu-liu/GenDexGrasp

Topic: Model-based Motion Planning

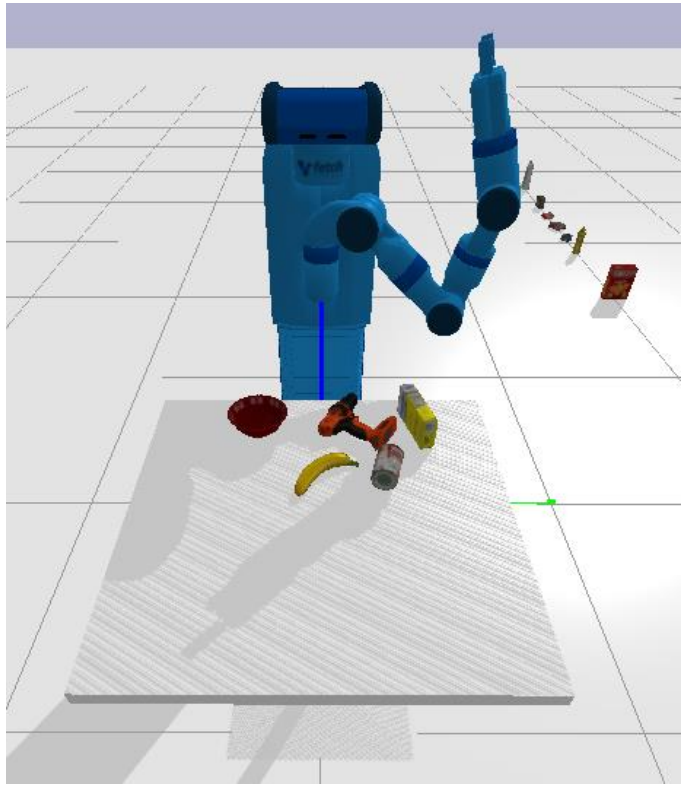




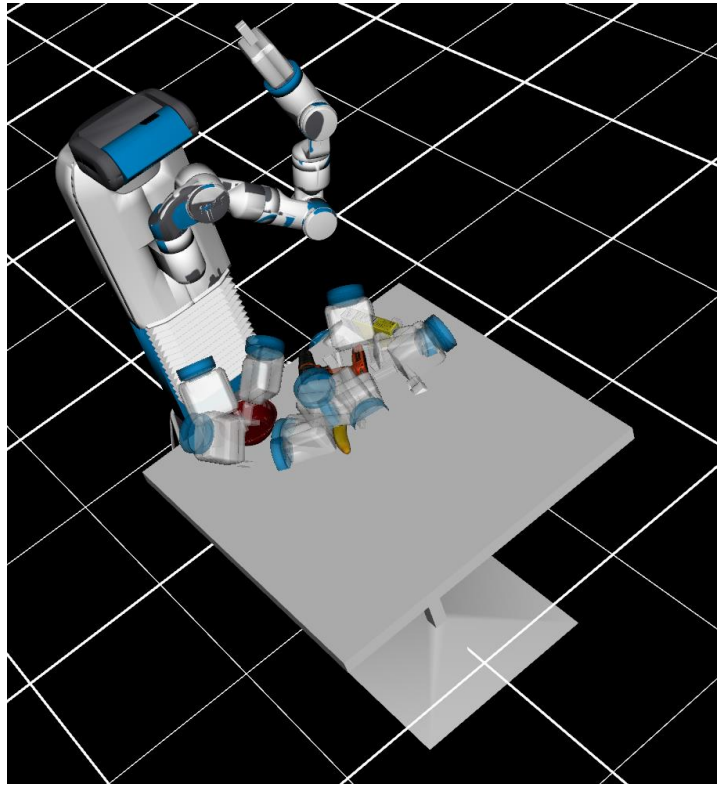
https://opensource.fetchrobotics.com/icra-challenge/2019/01/28/tutorial.html

Moveit https://moveit.ros.org/

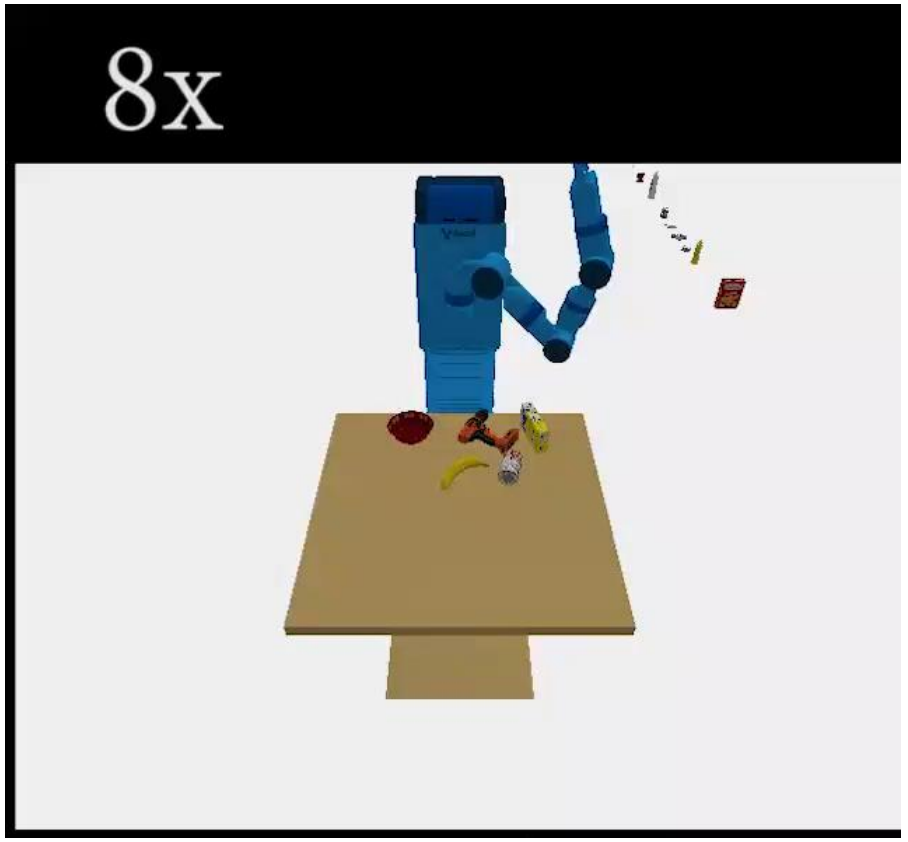
Topic: Model-based Trajectory Optimization



(a) Task Space



(b) Grasp Planning



(c) Grasp Trajectory Optimization

Xiang et al., IROS, 2024

https://irvlutd.github.io/GraspTrajOpt/

Topic: Learning-based Top-Down Grasping

https://ai.googleblog.com/2018/06/scalable-deep-reinforcement-learning.html

QT-Opt: Scalable Deep Reinforcement Learning for Vision-Based Robotic Manipulation. Kalashnikov, et al., 2018 https://arxiv.org/abs/1806.10293

Topic: Learning-based Top-Down Grasping

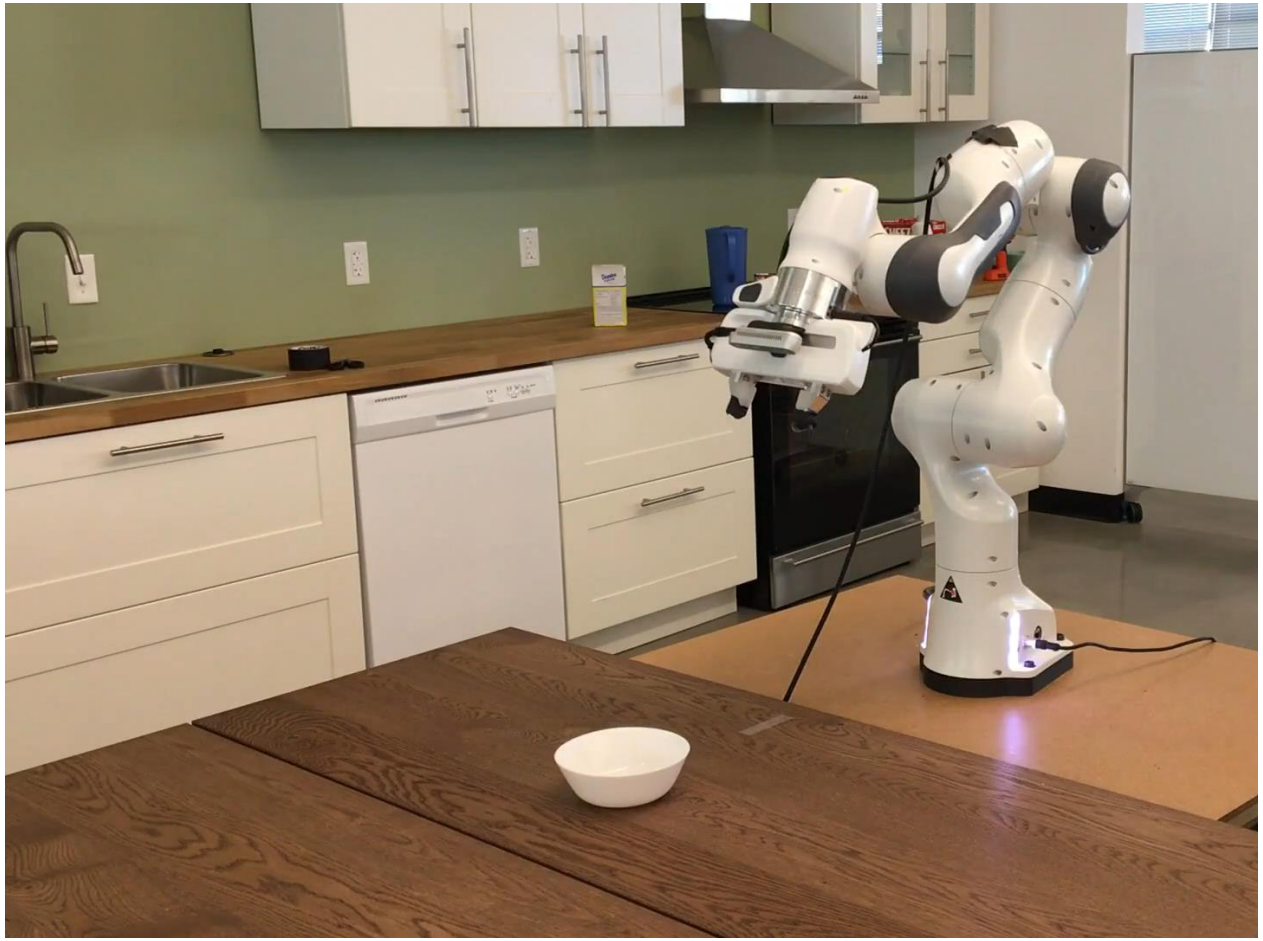
Sample Efficient Grasp Learning Using Equivariant Models. Zhu et al. RSS, 2022

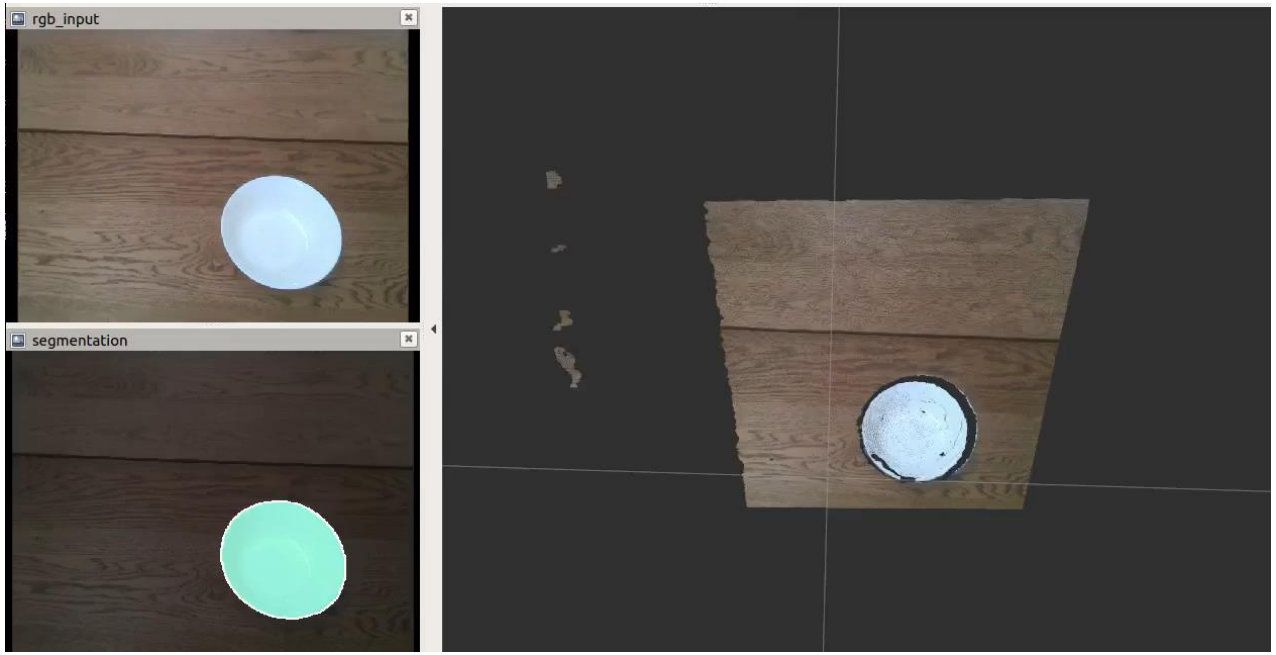
https://zxp-s-works.github.io/equivariant_grasp_site/

Topic: Learning-based 6D Grasping

6-DOF GraspNet: Variational Grasp Generation for Object Manipulation. Mousavian et al., ICCV'19
https://arxiv.org/abs/1905.10520

Topic: Learning-based 6D Grasping





Goal-Auxiliary Actor-Critic for 6D Robotic Grasping with Point Clouds. Wang et al., CoRL'21

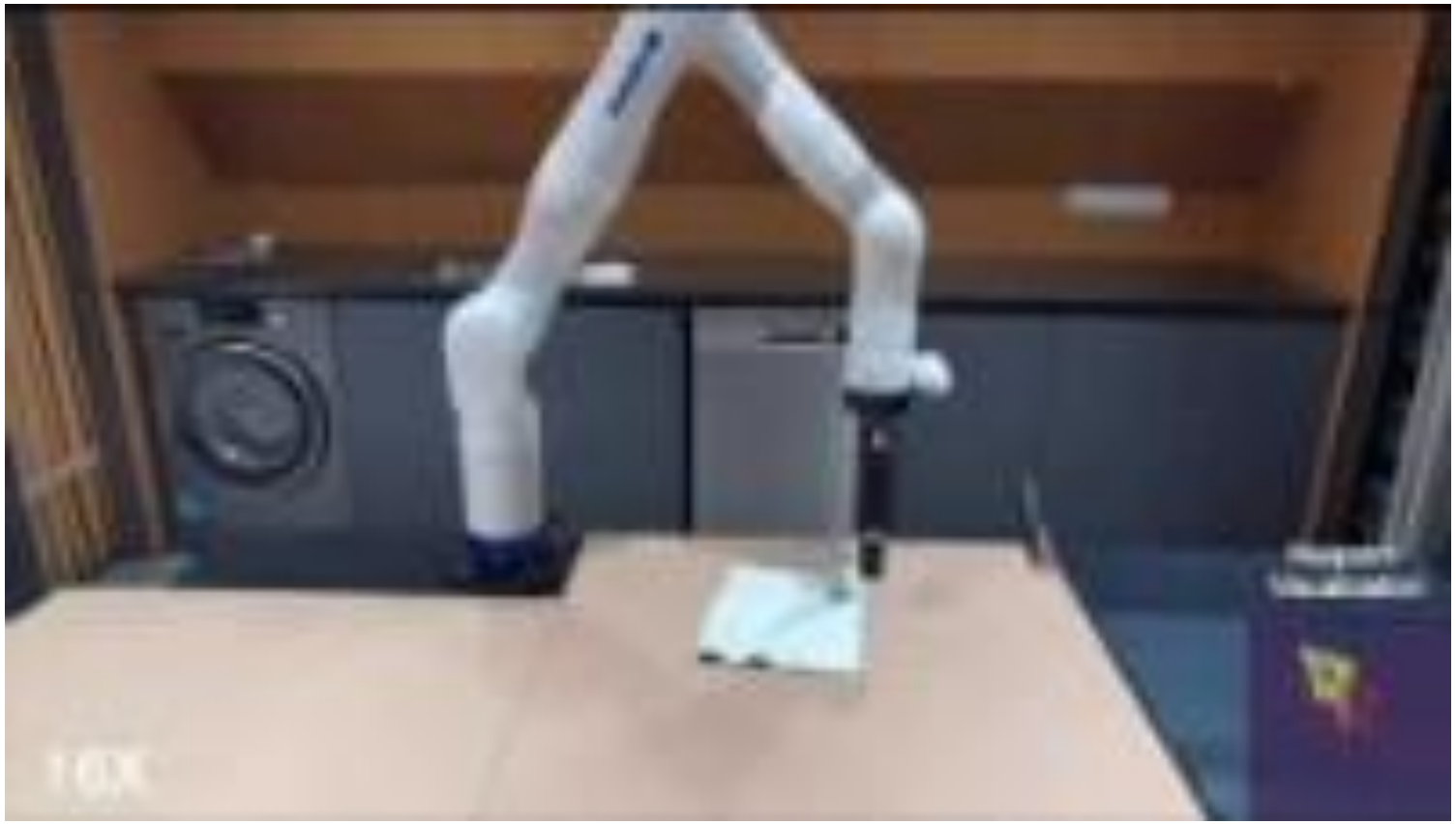
https://sites.google.com/view/gaddpg

Topic: Articulated Object Manipulation

https://hyperplane-lab.github.io/vat-mart/

VAT-Mart: Learning Visual Action Trajectory Proposals for Manipulating 3D ARTiculated Objects, Wu et al., ICLR'22

Topic: Deformable Object Manipulation



Learning Latent Graph Dynamics for Visual Manipulation of Deformable Objects. Ma et al., ICRA'21.

https://arxiv.org/abs/2104.12149

Topic: Mobile Manipulation

https://www.youtube.com/watch?v=ZQknooga8A0

Topic: Mobile Manipulation

- TidyBot

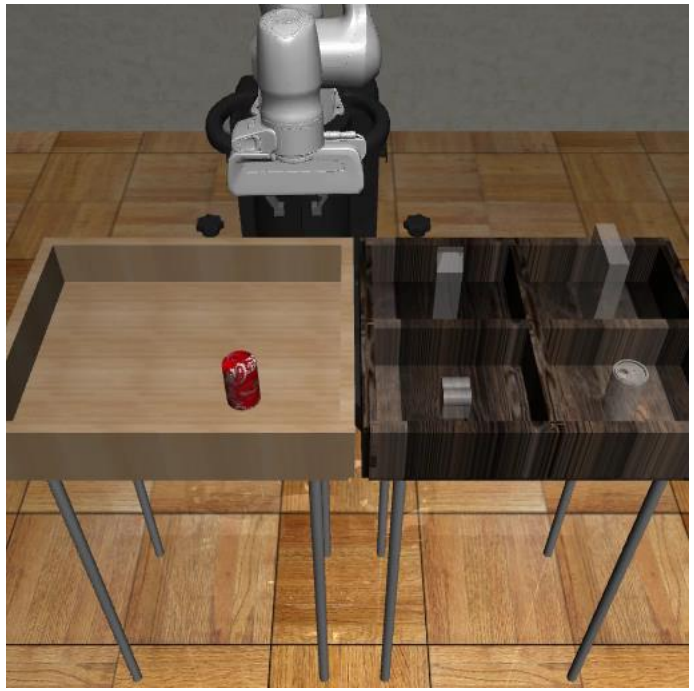
https://tidybot.cs.princeton.edu/

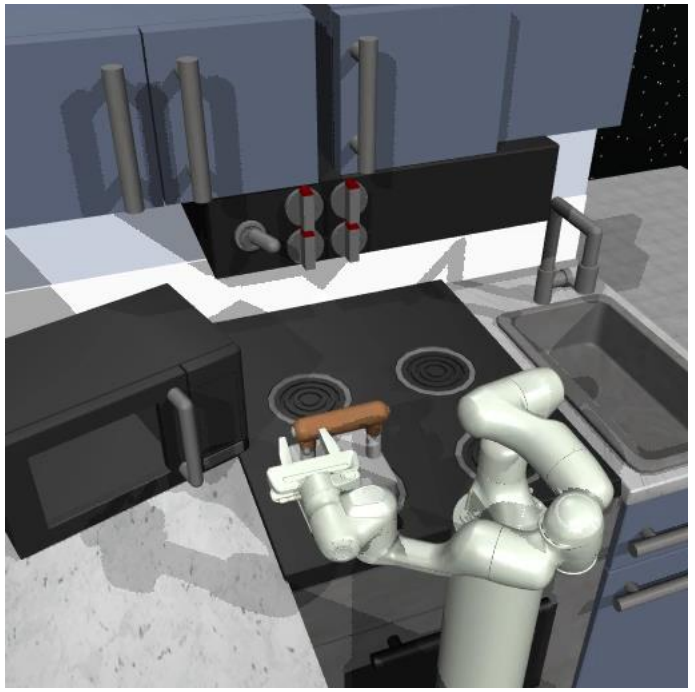
Topic: Language-guided Manipulation

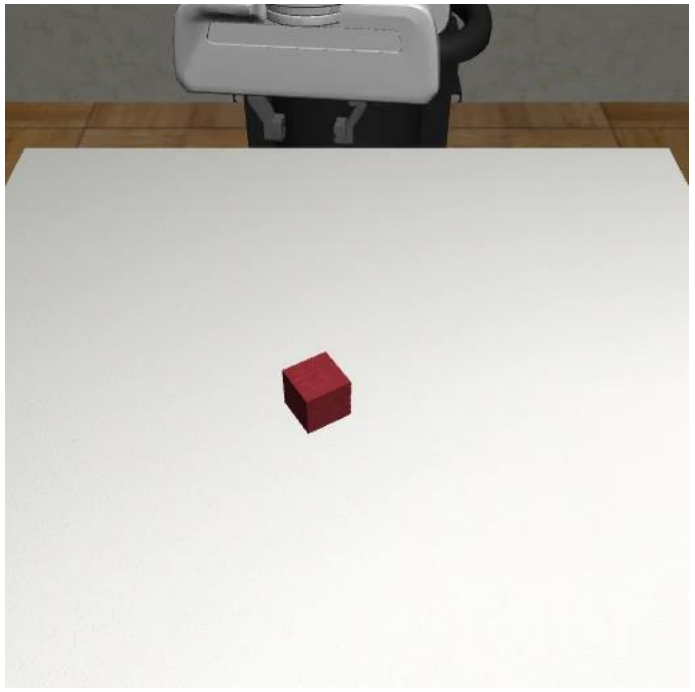
https://say-can.github.io/

Topic: Imitation Learning for Manipulation

- Diffusion policy

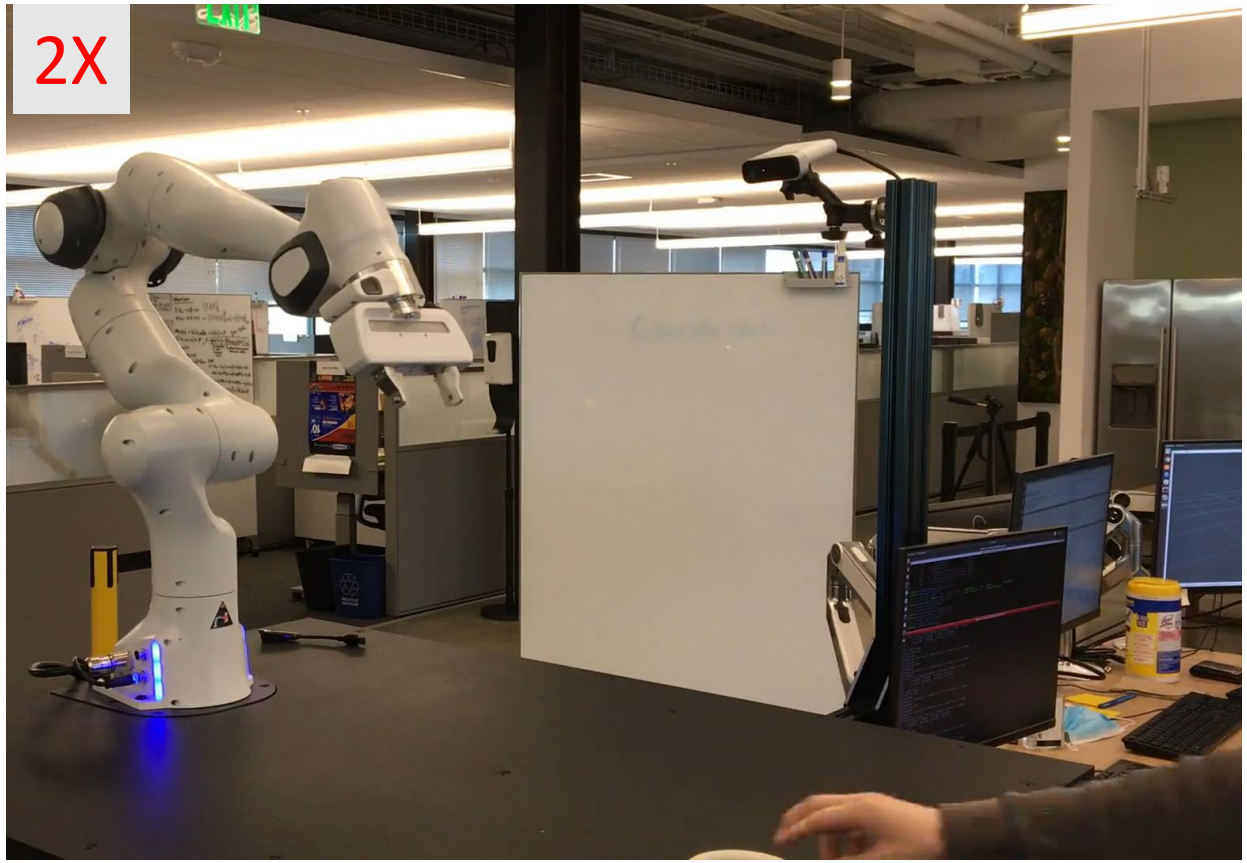


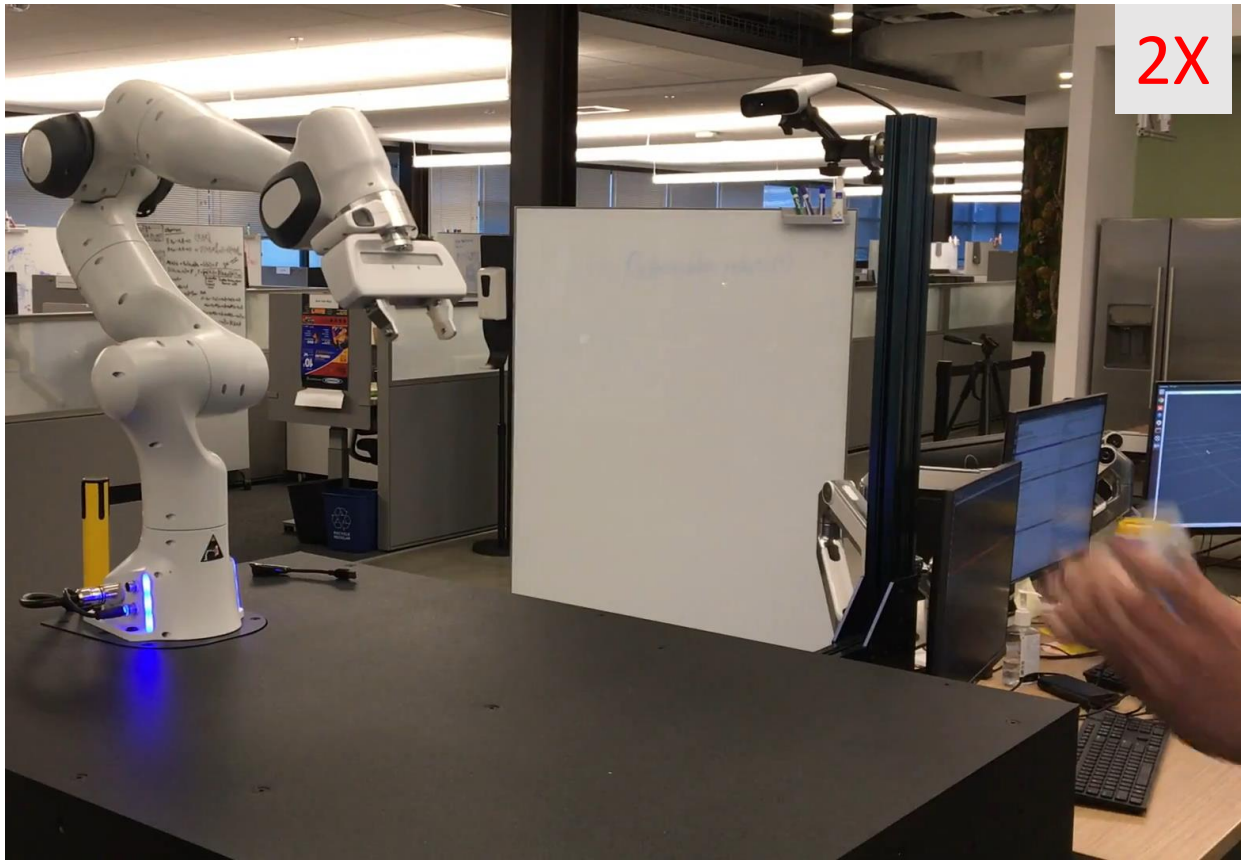




https://diffusion-policy.cs.columbia.edu/

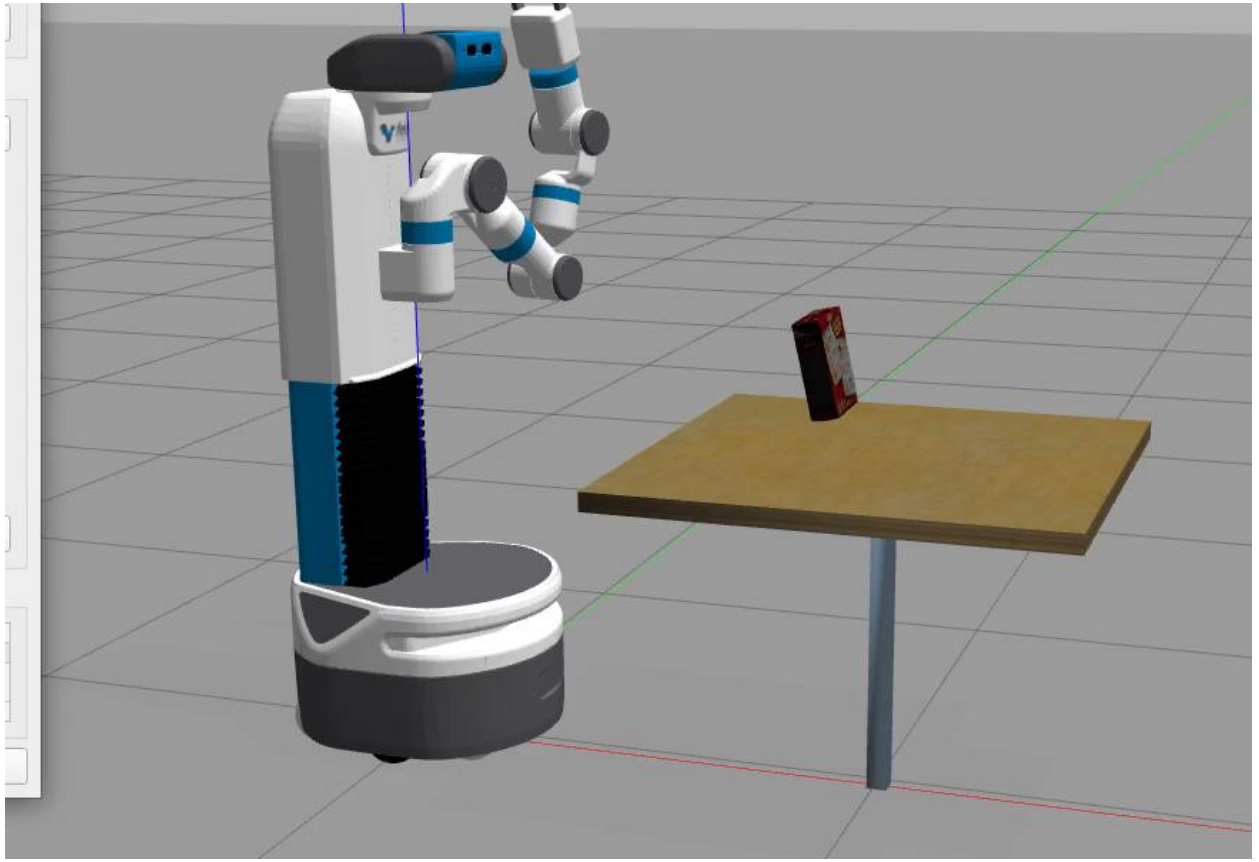
Topic: Human-Robot Handover





Goal-Auxiliary Actor-Critic for 6D Robotic Grasping with Point Clouds
Lirui Wang, Yu Xiang, Wei Yang, Arsalan Mousavian and Dieter Fox
In Conference on Robot Learning (CoRL), 2021.

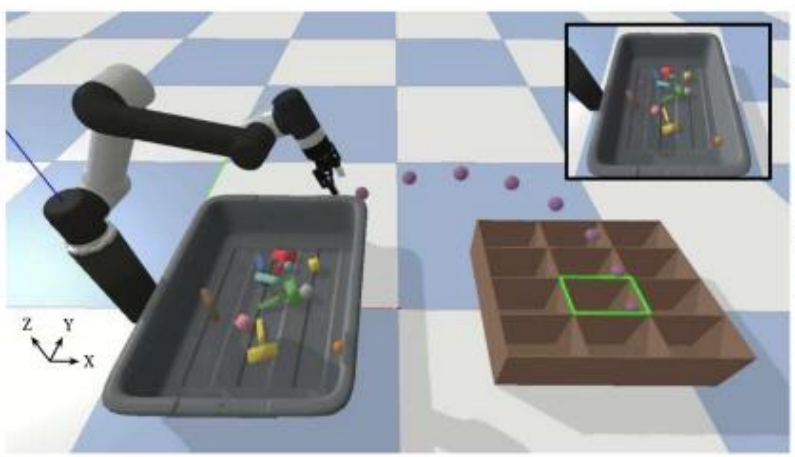
Simulator: Gazebo

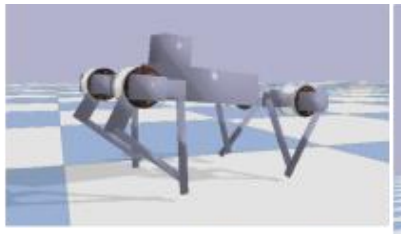


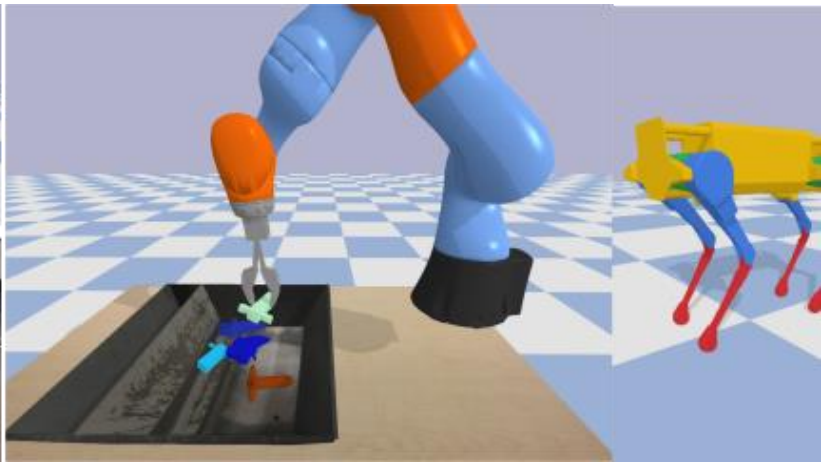
- Integrated with ROS

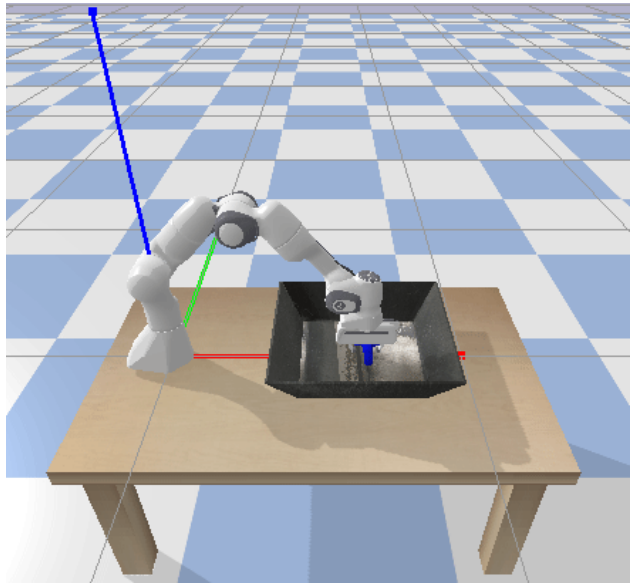
https://gazebosim.org/home

Simulator: PyBullet





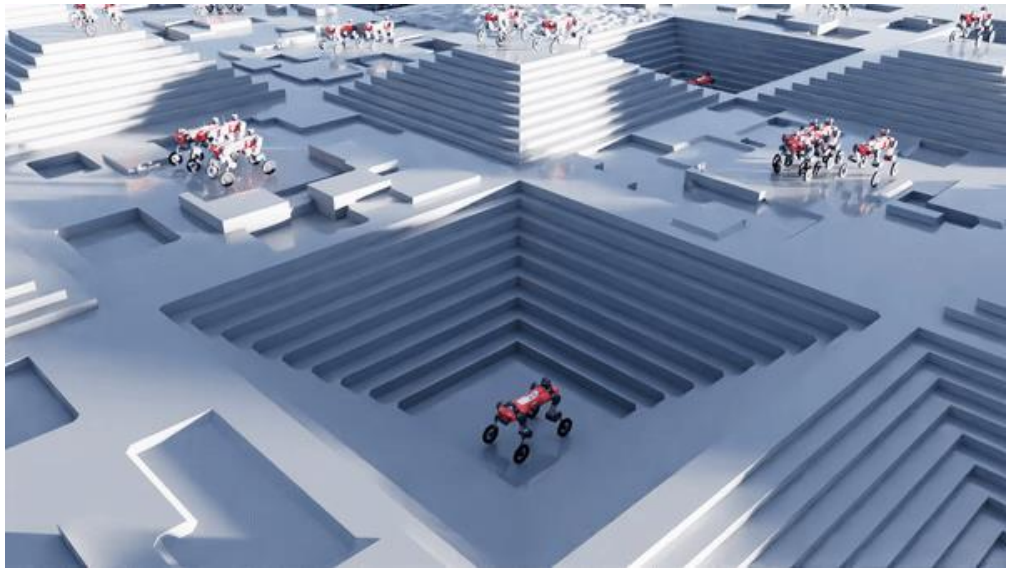


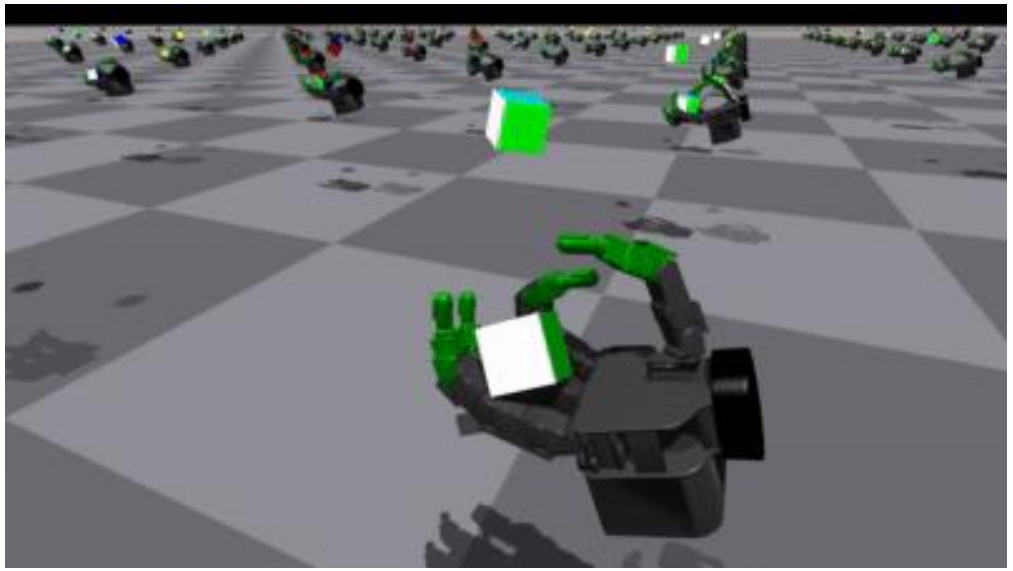


- Python interface

https://pybullet.org/wordpress/

Simulator: NVIDIA Isaac Sim/Gym

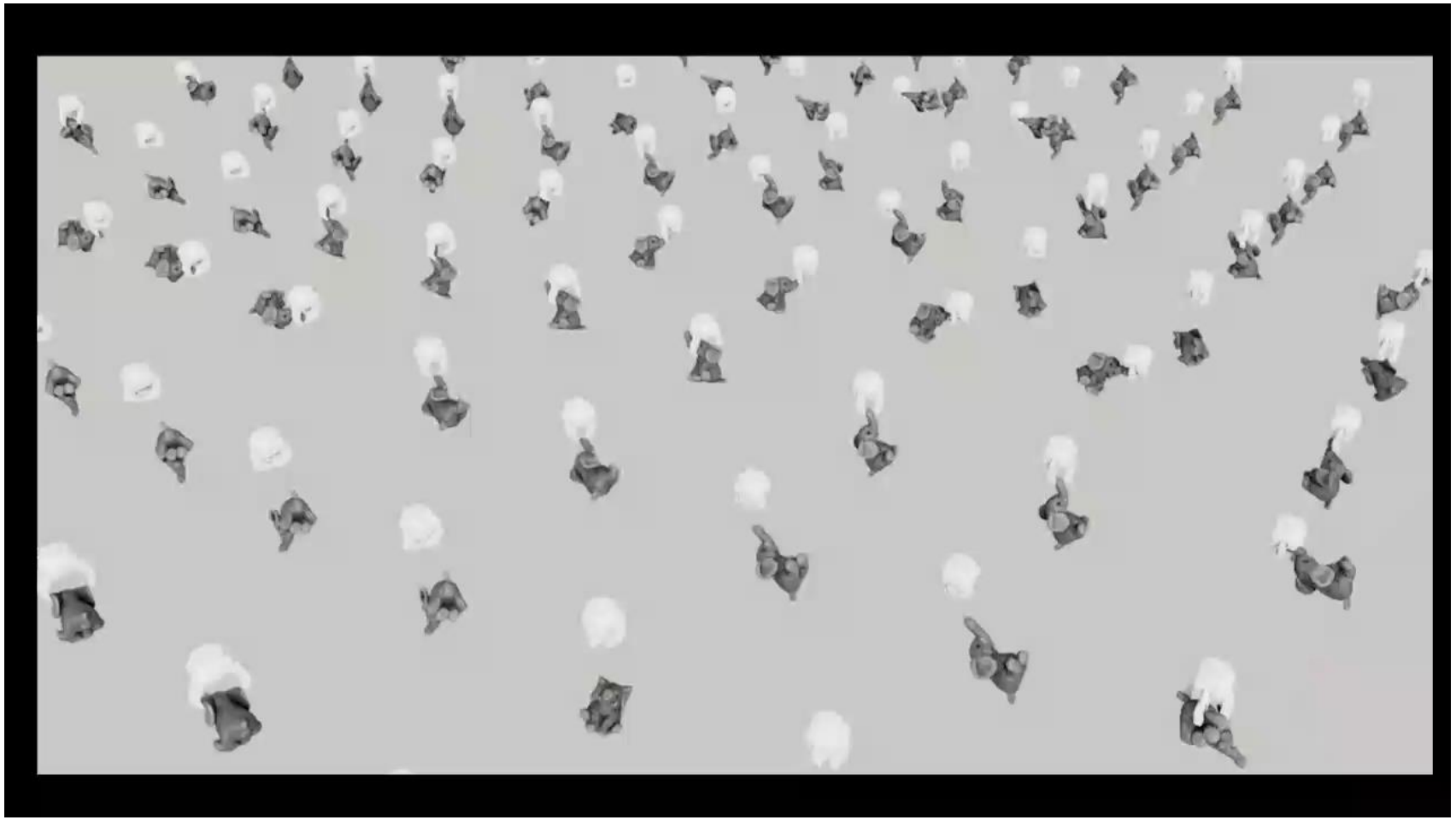




- GPU acceleration
- Parallelization of thousands of environments

https://developer.nvidia.com/isaac-gym https://github.com/NVIDIA-Omniverse/IsaacGymEnvs

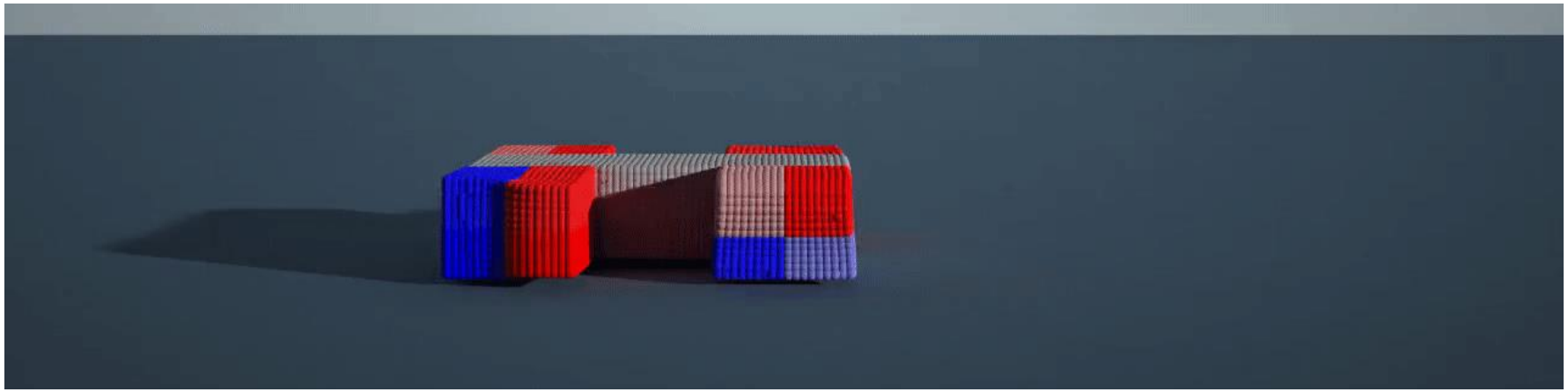
Simulator: NVIDIA Isaac Sim/Gym

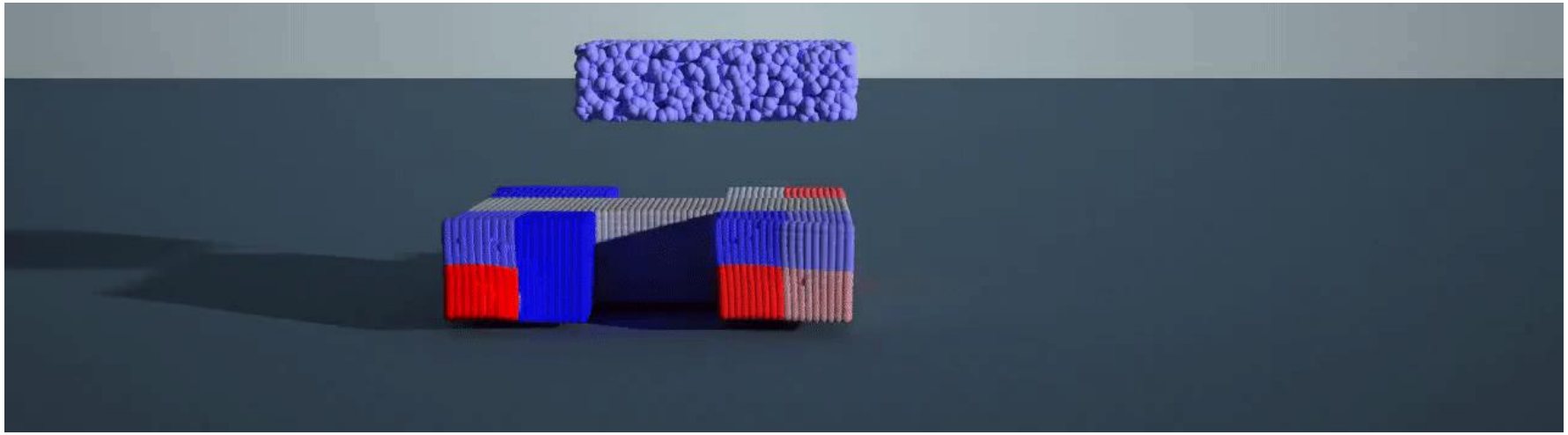


https://irvlutd.github.io/MultiGripperGrasp/

Simulator: DiffTaichi

- Deformable objects and fluid https://github.com/taichi-dev/difftaichi?tab=readme-ov-file





Simulation Environment: iGibson

Fully-Interactive and Photorealistic

15 scenes annotated from real-world homes

Support 12000+ scenes from CubiCasa5K and 3D-Front

Physical Interaction with Articulated Objects

More than 500 object models

Sourced from open source datasets and cleaned up

Articulated objects can be operated by agents

https://svl.stanford.edu/igibson/

Simulation Environment: ManipulaTHOR

iTHOR

RoboTHOR

https://ai2thor.allenai.org/manipulathor

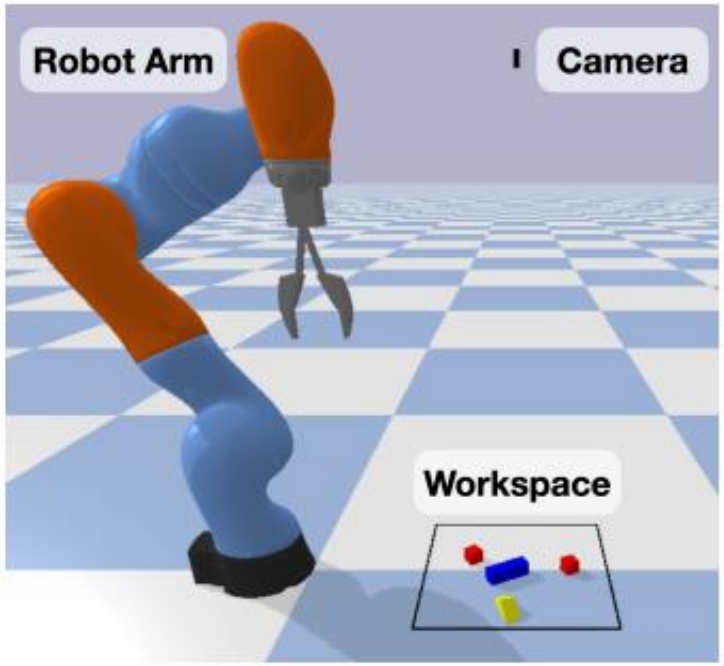
Simulation Environment: Habitat-sim

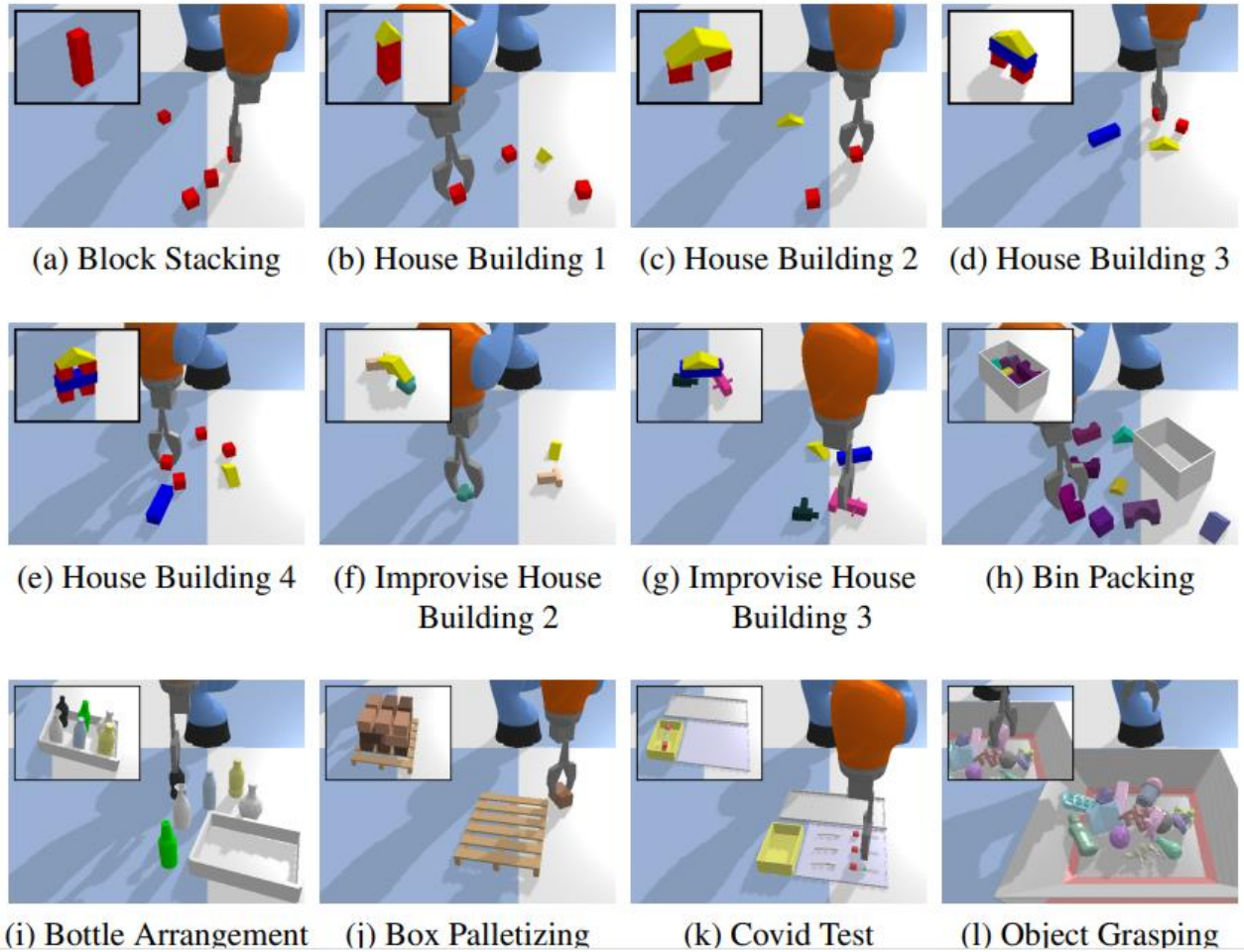
https://github.com/facebookresearch/habitat-sim

Simulation Environment: SAPIEN

https://sapien.ucsd.edu/

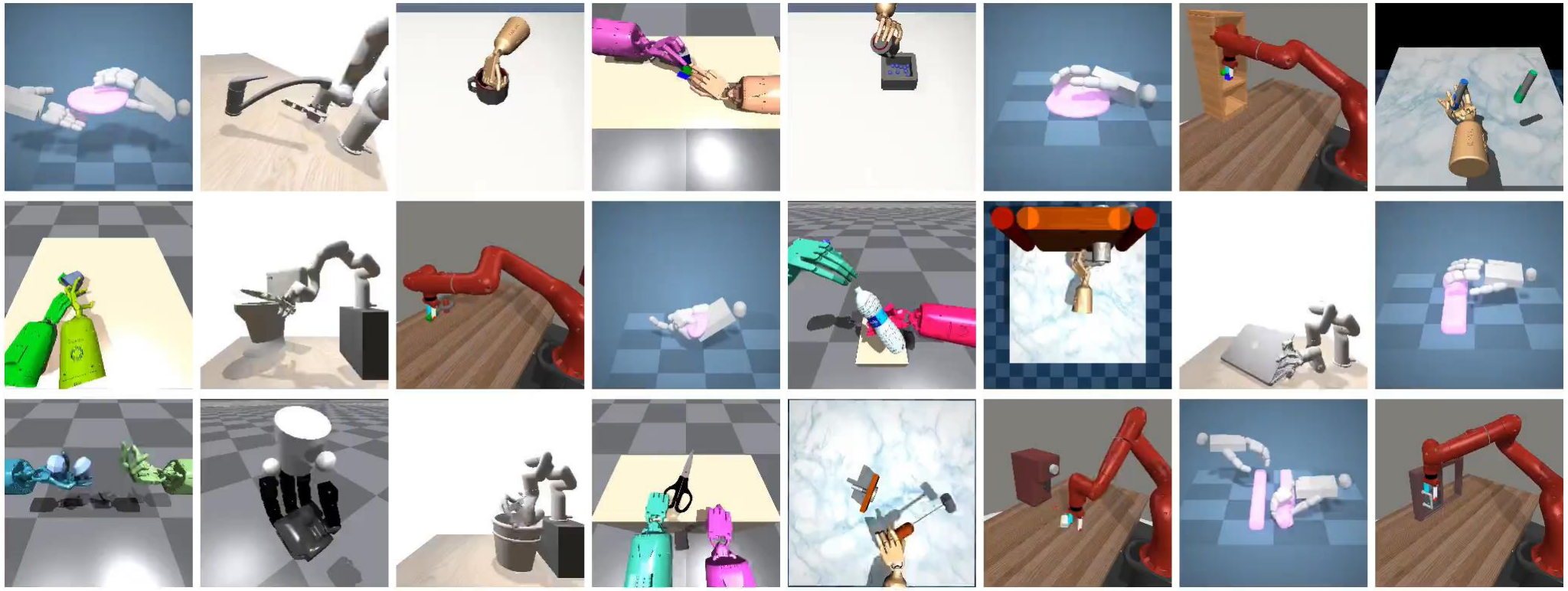
Simulation Environment: BulletArm





BulletArm: An Open-Source Robotic Manipulation Benchmark and Learning Framework. Wang et al. 2022
https://arxiv.org/abs/2205.14292

Manipulation Benchmarks in Simulation



7 benchmarks: Adroit, Bi-DexHands, DexArt, DexDeform, DexMV, HORA, and MetaWorld

3D Diffusion Policy: https://3d-diffusion-policy.github.io/

Resources from IRVL

- 6D object pose estimation https://github.com/IRVLUTD/gdrnpp_bop2022
- Unseen object segmentation https://github.com/YoungSean/UnseenObjectsWithMeanShift
- GraspIt! https://github.com/IRVLUTD/neuralgrasps-dataset-generation/tree/multigrippergrasp

- Contact-GraspNet https://github.com/IRVLUTD/contact_graspnet
- Grasping trajectory optimization https://github.com/IRVLUTD/GraspTrajOpt
- Grasping in Gazebo or Isaac Sim https://github.com/IRVLUTD/SceneReplica
  https://irvlutd.github.io/MultiGripperGrasp/

Propose Your Projects

- Which topic to work on?
  - Grasping? Language-guided Manipulation? Mobile Manipulation?
- What specific problem to work on within the chosen topic?
  - Model-based grasping? Motion planning? RL for grasping? Etc.
- Which simulation environment to use?
  - Gazebo with ROS? iGibson? Isaac Gym? Etc.
- Which track is your project?
  - Research-oriented? Application-oriented? Implementation-oriented?

Discussion