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Learning to Manipulate Deformable Objects - Plastic Bags

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Introduction

Goal

- Learning to manipulate a deformable bag using a manipulator.
- Build an environment using Isaac Sim physics engine.
- Learn to lift and open the bag using a visual policy.

Related Work

- Autobag [1] teaches robots to open plastic bags and insert objects with some predefined manipulation primitives.
- Bag all you need[2] develops a versatile bagging approach for diverse objects through learning.
- Dedo[3] addresses dynamics involving deformable objects in motion.

[1] Chen, Lawrence Yunliang, et al. "Autobag: Learning to open plastic bags and insert objects." 2023 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2023.

[2] Bahety, Arpit, et al. "Bag all you need: Learning a generalizable bagging strategy for heterogeneous objects." arXiv preprint arXiv:2210.09997 (2022).

[3] Antonova, Rika, et al. "Dynamic environments with deformable objects." Thirty-fifth Conference on Neural Information Processing Systems Datasets and Benchmarks Track (Round 2). 2021.

Bag

- Isaac Sim from Nvidia is the physics engine used to simulate the dynamics of a bag.
- The Bag in the simulator is modified in a way to have a different colored rim.
- Properties of the simulation bag are that of a cloth to achieve a close-to-realistic simulation of the bag.

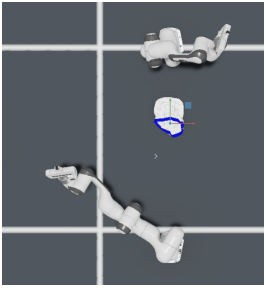
Figure: Bag with a blue coloured rim.

Environment

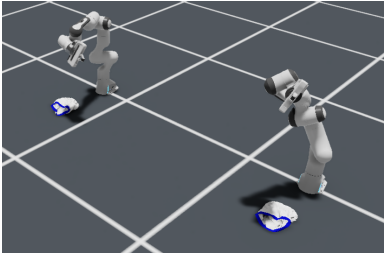
- Environment is created using Isaac Orbit[4] with a manipulator and a bag.
- Various bag properties can be tweaked, and multiple manipulators can be added.
- Multiple environments can be trained in parallel.

[4] Mittal, Mayank, et al. "Orbit: A unified simulation framework for interactive robot learning environments." IEEE Robotics and Automation Letters (2023).

Environment



(a) Environment with two manipulators.



(b) Environment replicated twice.

Figure: Configuration of the environment with multi-robot and multi environments.

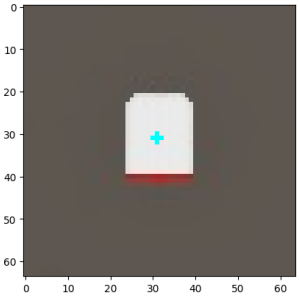
Experiments: BagLift

Bag Lift

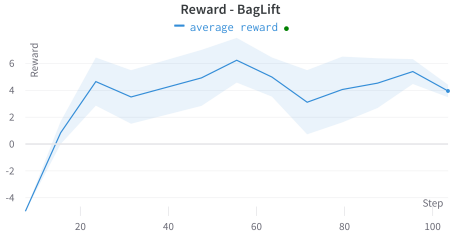
- A visual policy[5] is trained to get the pick point of the bag to lift the bag above the ground.
- A positive reward is given when the manipulator successfully lifts the bag and a negative reward for an unsuccessful attempt.
- UNet is pre-trained to get the segmentation of the bag.

[5] Wu, Yilin, et al. "Learning to manipulate deformable objects without demonstrations." arXiv preprint arXiv:1910.13439 (2019).

Results: BagLift



(a) Predicted grip point from the UNet.



(b) Training reward for baglift environment.

Figure: Results of baglift environment.

Experiments: BagOpening

Bag Opening

- A visual policy[6] is trained to get the pick point and a place point to open the bag to maximum opening.
- A pick position is selected from the network, based on the pick position a place position is selected, and a drag from pick $\rightarrow$ place is performed.
- Reward is given when the area of the bag rim is increased from the previous configuration after performing an action.

[6] Blanco-Mulero, David, et al. "QDP: Learning to Sequentially Optimise Quasi-Static and Dynamic Manipulation Primitives for Robotic Cloth Manipulation." arXiv preprint arXiv:2303.13320 (2023)

Results: BagOpening

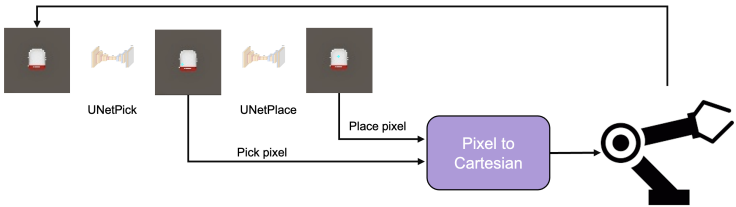


Figure: Input image from the environment is passed through UNet to get a pick position. Pick position and image are used to get a place position.

Results: BagOpening

Figure: Training reward for bagopening environment.

- The visual policy is able to learn the pick and place positions as the simulation environment is perfect in a sense (the bag and the background can be easily distinguished)

Shortcomings

- Manipulator approaches pick/place point in only one orientation.
- The Inverse Kinematics controller used is not able to solve in some instances.
- Bag slips out of manipulator's grip.
- The task at hand is to increase the opening area of the rim at each step, the maximal opening goal set is not reached.

Miscellaneous

- A docker image with Orbit support is built and hosted on Dockerhub.[7]
- Isaac Orbit Environments are set to run on Triton HPC using the docker image from above.[8]
- Synthetic camera data generation from the simulator environment.

[7] DockerHub link

[8] More details can be found at documentation.

Future Work

- Use more manipulation primitives for the BagOpening task.
- Compare with already existing techniques and benchmarks.
- Realisation on the Franka.