Homework1

Homework1 is the first part of midterm project. You will learn to apply the knowledge about SE(3) geometry and robot kinematics. Besides, it will help you get familiar with Sapien.

Getting started

Please follow the document of Sapien to install the environment. Currently, only Ubuntu is fully supported. MacOS is experimentally supported and feel free to report any bug.

```
# Use the correct pip if you are using virtualenv or conda.
pip3 install sapien
pip3 install opencv-python
pip3 install ikfast-pybind
```

It is suggested to run the tutorial (at least the minimal example) provided by Sapien before the next step. It is also suggested to use an editor, like VSCode or Pycharm, so that you can jump to definitions to get an idea of APIs.

Instruction

The goal of this assignment is to achieve:

- hand-eye calibration
- move the end-effector to certain positions

The starter code provides these files:

- hw1.py: run this file to debug and evaluate; not necessary to modify
- hw1_env.py: implement this file
- stacking_env.py: provide basic functions; not necessary to modify

Hand-eye calibration

For hand-eye calibration, you need to implement `capture_calibration_data` and `compute_cam2base`.

We have provide some predefined sets of joint poses `qpos_list` in `capture_calibration_data`. For each set of joint poses (9 DoF), you need to collect two transformations `ee2base` and `marker2cam`. `ee2base` is the transformation from the end-effector to the robot base, which should be returned by `get_current_ee_pose`. `marker2cam` is the pose of the marker (chessboard) in the camera coordinate system, which should be returned by `get_current_marker_pose`. To implement

the marker pose estimation, we refer you to OpenCV tutorials.

Based on collected calibration data, `compute_cam2base` should estimate the transformation `cam2base` from the camera to the robot base. You might implement Tsai or other methods.

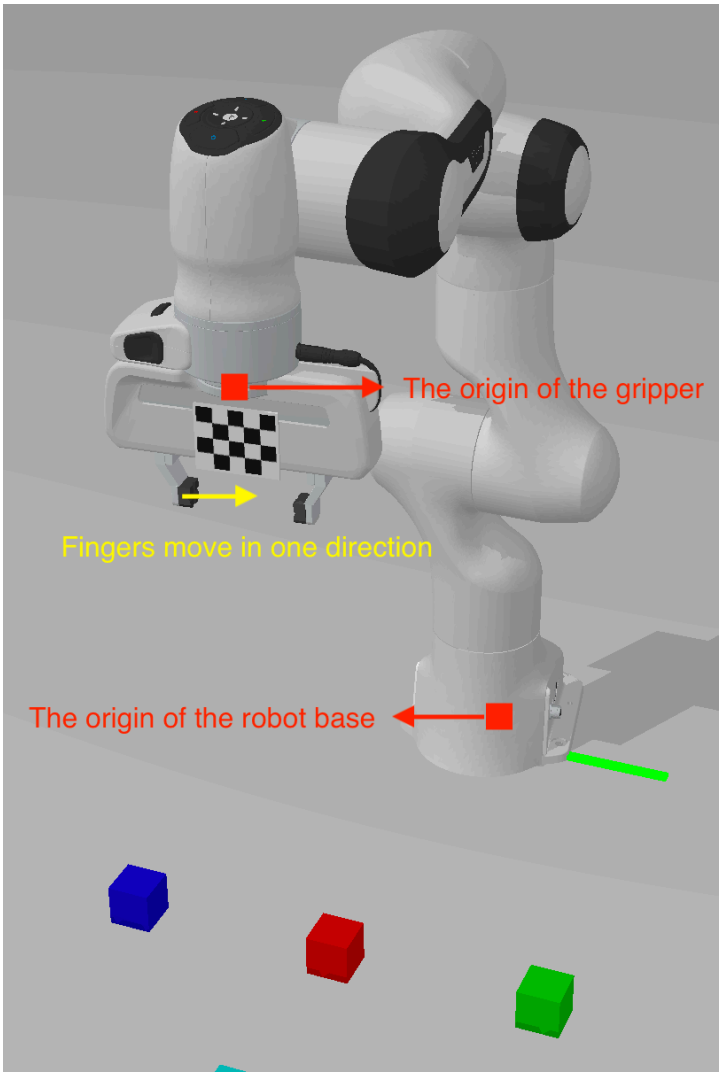
> Please note that the setting in this project is **eye-to-hand**, where the camera is fixed to world. However, the example in the lecture is **eye-in-hand**. You will need some small modification of the original eye-in-hand calculation.

Robot kinematics

To grasp objects, you need to implement `compute_grasp_qpos`, which returns the set of joint poses `qpos` (9 DoF) given a target position. In this assignment, each element of `qpos`, which is a list, represents the angle of a joint.

For this specific assignment, grasping a box is relatively easy. For each box, you will be provided with its observed point cloud, which is observed by the camera. Note that usually the camera can observe at least two complete faces of a box, which is roughly enough to estimate its 3D position. Since the box is axis-aligned in the camera system, which means you can acquire the position and the size of the box by computing minimal and maximal coordinates of its 3D point cloud.

To grasp an axis-aligned box with our specific two-finger gripper (see the figure below), you can set the gripper downward (rotation) and place it about above the top face of the box (position).



> The distance between two fingers is larger than the size of the box. Taking the size of the gripper and two fingers into consideration, you need to move the origin of the gripper about 0.11 (you can try other values) above the center of the top face of the box.

According to the 3D position of an axis-aligned box in the camera system and `cam2base`, you can acquire the 3D position of the target box relative to the robot base. Given this position, you can compute a target pose, as illustrated above. Finally, you can call `compute_ik` to calculate `qpos` given the target end-effector (gripper) pose. Note that `compute_ik` returns the joint poses without those of two fingers. You need to append the poses of two fingers to `qpos` returned by `compute_ik`, e.g., `qpos = self.compute_ik(gripper_pose)[0]; qpos = qpos + [0.04, 0.04]`.

Functions to implement

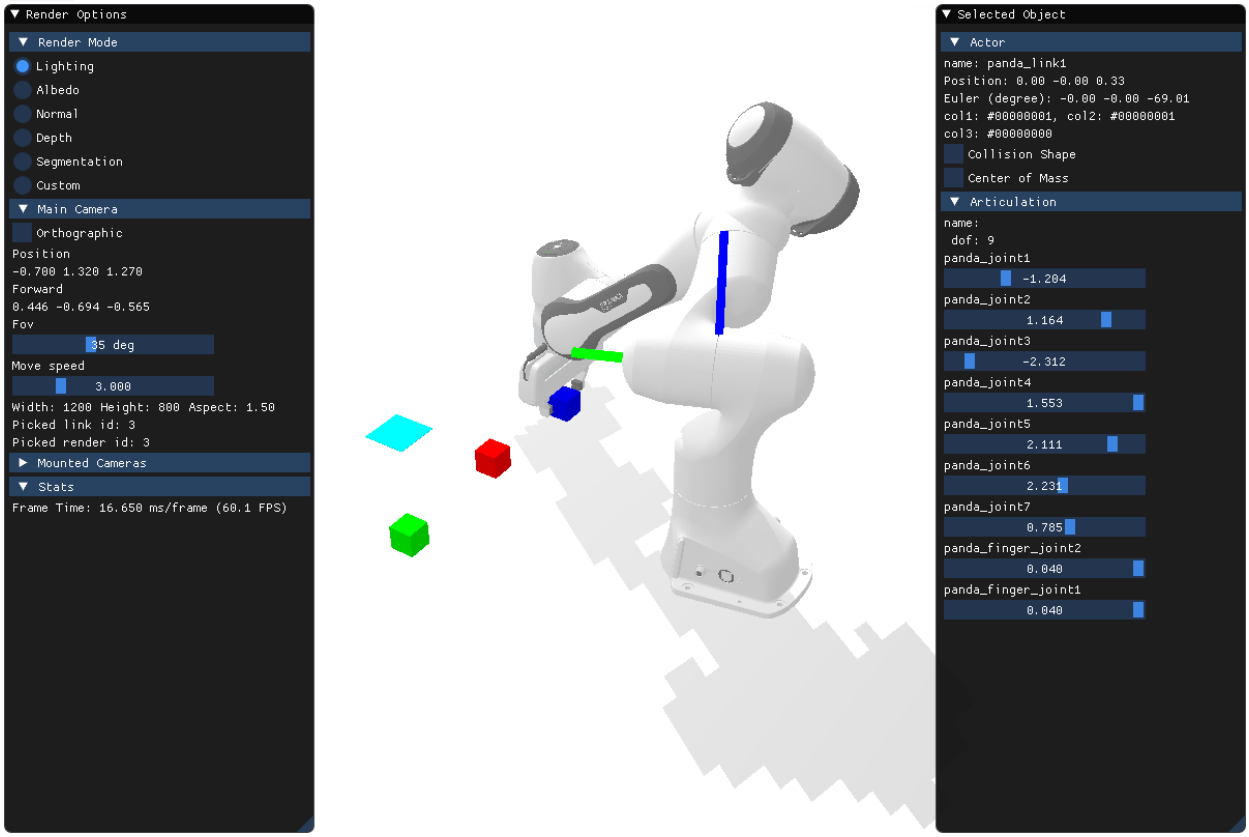
It is suggested to implement the following functions in order:

- pose2mat
- get_current_marker_pose
- capture_calibration_data
- compute_cam2base

- compute_pose_distance
- compute_grasp_qpos

Hints

- `qpos` refers to the set of joint poses. The robot is controlled by specifying all the joint poses. The DoF of the robot used in the assignment is 9. The 7th joint is the end-effector. The 8th and the 9th joints are two fingers.
- You can check the details of the robot by clicking on it. The example is illustrated in the figure. `qpos` can be found on the right panel (Articulation) of the interface.



- To articulate a robot, you can use `self.robot.set_qpos(qpos)`. The function will set the joint poses to the target ones.
- If you do not call `self.step()`, the world is just rendered instead of being simulated.
- The pose of an object is represented by the class `Pose` in Sapien. It has two attributes: `p` for 3D position and `q` for 4D quaternion.
- The camera used in the assignment is an RGB-D camera.
- The boxes are axis-aligned in both the camera and the world (robot base) coordinate system.
- If you fail to implement hand-eye calibration, you can use GT `cam2base` for robot kinematics.

Grading

The assignment will be evaluated by running hw1.py to check the correctness. If you only manage to achieve one objective (hand-eye calibration or robot kinematics), you will receive half of the full score. It is not necessary to import extra libraries. You will also lose points if you use extra libraries like `scipy` and `transform3d`. Late submission will also lose points.

Turning it in

The deadline of the midterm project (homework1 and homework2) is May 10th, 12 p.m. For homework1, you only need to submit hw1_env.py to gradescope. You are not required to submit a report. One submission for each team.

> Gradescope entry code: M5WDJG

Academic integrity

You are allowed to work in teams, but are not allowed to use the answers developed by others. You are not allowed to copy online resources, like GitHub repositories. Please ask the instructor first if you are not sure whether you can refer to some resources.

If the work you submit is determined to be other than your own, you will be reported to the Academic Integrity Office for violating UCSD's Policy on Integrity of Scholarship.