Machine Learning and Optimal Control
CS 484 / CS584 2024

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Learning Dexterous Robotic Manipulation (Ver 1.0)

1. Project Objectives

- Get familiar with robotic simulation.
- Understand intelligent robot manipulation.
- Develop an RL algorithm to control the robot accomplish pick and place task.

2. Procedure

1. Environment Setup (using your virtual environment)
    - Install stable baseline3 library in your virtual environment.
        - pip install stable-baselines3
        - Documentation: https://stable-baselines3.readthedocs.io/en/master/
    - Setup Pybullet Environment (you should have installed it).
        - Pybullet Reference: https://github.com/bulletphysics/bullet3
    - Install other necessary library when prompted
2. Run **test.py** to test the environment:
    - You would see a robot and an object in the environment. The environment is ready!
    - Drag the toolbar to control the robot arm (Only the top 3 bars that control the robot arm are enabled)
3. Modify the **sawyerEnv.py** file:
    - Change the value of **self.index** in **line 98** to switch object. There are 8 objects with index from 0 to 7. Refer to "Object_assignment.pdf" for the randomly assigned object for each of you.
    - Implement the **reward_s1** function in **line 432** to encourage the robot hand to move to the grasp location.
        - Define the reward function under "implement your function here" section using the helper variables in the reward_s1 function.
    - Once the hand arrives the grasp location, it will grasp and pick up the object automatically.

- You shouldn't need to modify the other part of the file.

4. Modify the **train.py** file:
   - Change the value of the parameter **timeStep** in **line 40** to decide the training time. The time is simulation time which is computer specific.
   - Choose or implement an RL model in stable_baseline3 to train the grasping task. Examples of using pre-implemented models: https://stable-baselines3.readthedocs.io/en/master/guide/examples.html
5. Run **evaluate.py** to evaluate the trained model. The success rate of the task is displayed in the terminal.

3. What you need to submit (35 points in total)

Note: CS 484 and CS 584 have different requirements.

- Functional codes (5 points): The codes will be evaluated by a test run.
  - sawyerEnv.py and train.py
- Demo illustration (5 points)
  - A short video that demonstrates a successful grasp.
- Project Report (25 points)
  - A project report should follow the IEEE conference format (1 point): https://www.ieee.org/conferences/publishing/templates.html
  - The report should include:
    - Introduction (3 points)
      - Background discussion on at least two topics, e.g., robotic manipulation, reinforcement learning, simulation, or other related topics of your choice (1 point)
      - Summary of procedure, method, or approaches (1 point)
      - Summary of the project conclusions or discoveries (concise and brief) (1 point)
    - Method (6 points)
      - Overall approach, e.g., simulation environment with a picture, models, framework, etc (2 points)
      - Technical description of the applied RL algorithm/methods (2 points)
      - Show the equation or function of the reward (**math equations not codes**) (2 points)
    - Results (3 points)
      - Success rates of grasping and a brief review of it (1 point)

- Examples with pictures of successful and failed grasping trials AND a brief explanation on them (e.g., knocked the object to the ground, if there are any) (2 points)

- Discussion of results (10 points)
  - CS 484 students only
    - Discuss the advantages and disadvantages of the RL algorithms. Why was it successful or not? (5 points)
    - Discuss the designed reward function. What are the key parameters and how were the parameters selected? (5 points)
  - CS 584 students only
    - Discuss the advantages and disadvantages of the RL algorithms. Why was it successful or not? (3 points)
    - Discuss the designed reward function. What are the key parameters and how were the parameters selected? (3 points)
    - Review the literature and discuss one (1) approach/idea/environment/setup that could potentially generate improved grasping performance. (4 points)
- Conclusion (1 points)
  - Conclude the report, what you have done, what results you have got, what worked and what did not.
- Reference (1 point)