Lab 9: Robot Arm Lab

Introduction to Robotics
Spring 2024

Lab TAs: Freda Su & Preethi Krishnamoorthy

Table of Contents

Learning Goals

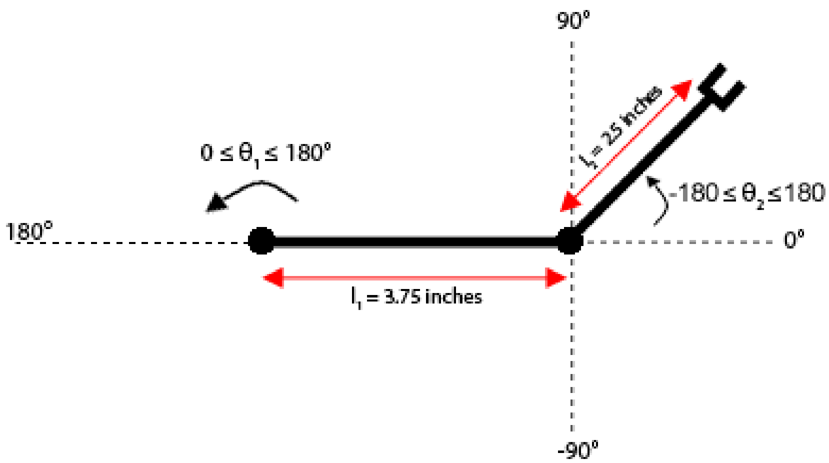
Students will build a two link RR robot arm and demonstrate inverse kinematics and path planning by safely navigating a known workspace.

Video Example

Link

Requirements

Arm Design

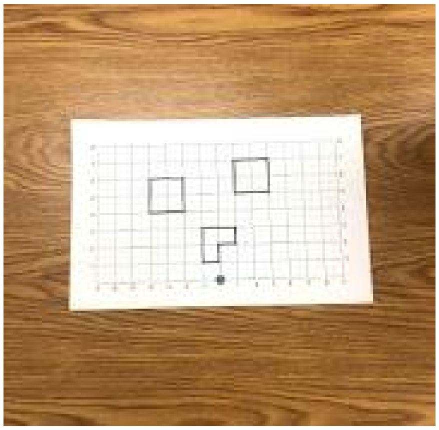


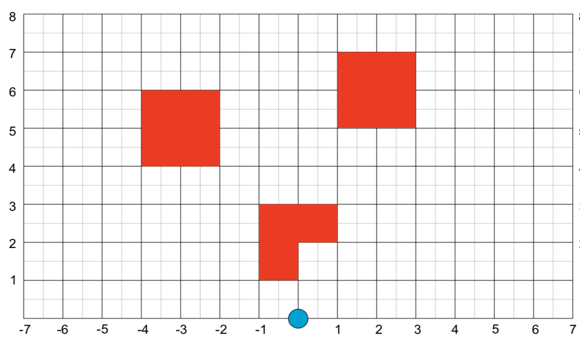
The arm should have a stable base that remains fixed in position during the demo. **Please attach something to the end effector that brings it within ½” of the board so we can make measurements.** You may use other arm lengths, but we can only guarantee that goals will lie in the C-space (of end-effector) of this arm configuration.

Playing Field

Students can choose to demo with their robot in either the horizontal or vertical orientations.

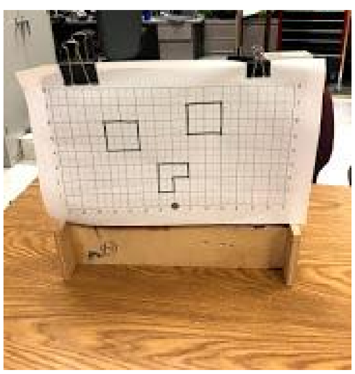
<u>Horizontal orientation</u>

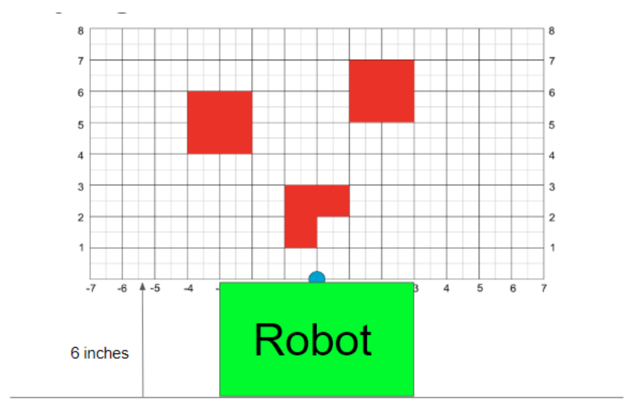




- The end effector cannot get over the obstacle, but the arm links can.
- Each block is ½ inch thick.

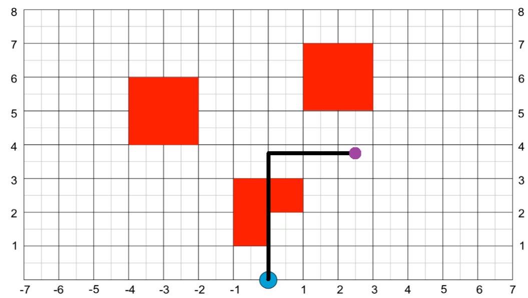
<u>Vertical Orientation</u>



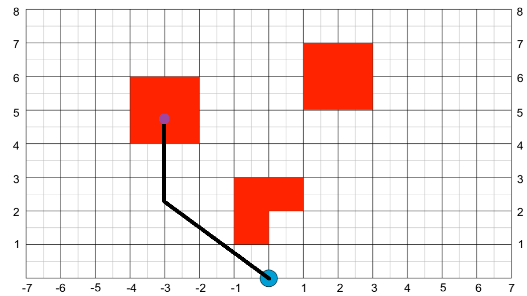


- You have maximum 6" clearance from table to the origin.
- Be sure to account for gravity and the weight of your arms!
- The end effector cannot get over the obstacle, but the arm links can.
- Each block is ½ inch thick.
- You get 10 points just for attempting the vertical orientation.

Example Orientations



Good configuration



Bad configuration (EE hitting obstacle)

Grading

The Demo will be on Wednesday, April 17th. Please sign up for your demo slot here: Demo Signup Sheet

Demo

- We will be conducting 3 trials (35 sec/trial).
- The starting configuration of each trial is the coordinate (6.25, 0).
- On demo day, you will be given three (x,y) positions A, B and C. (Unit: inches, refer to previous images for reference of coordinates)
- You should show a plot of your planned trajectory in either xy or theta space.
- Your robot must navigate from the starting configuration -> A -> B -> C
- Your arm should come to a complete stop at each position for at least 3 seconds so the grader can record the current position.

Score Calculation

Grading will be out of 100 pts. 70 pts will be from the demo and 30 pts will be from the Q&A session. If you choose the vertical configuration, you will get 10 bonus points (the total score is still capped at 100). The rubric can be found here: Rubric Link

Make sure to print out your rubric and bring it to the demo!

Trial Scoring

We will be conducting three trials. The final score will be based on the **best** of the 3 trials.

Each trial is worth a maximum of 70pts (or 80pts with vertical) with the distribution as follows:

- L2 Distance from EE to point A
  - 10 pts if within 0.5 inches
  - 5 pts if within 1.0 inches
  - 0 pts otherwise
- L2 Distance from EE to point B
  - 20 pts if within 0.5 inches
  - 10 pts if within 1.0 inches
  - 0 pts otherwise
- L2 Distance from EE to point C
  - 30 pts if within 0.5 inches
  - 15 pts if within 1.0 inches
  - 0 pts otherwise
- 10 points for displaying valid path planning
  - You should show the intended trajectory your arm will take before the trial
- -5 point/second penalty for going overtime (>35 seconds)
- -15 point penalty if EE hits obstacle or leaves workspace during trial
- Note that penalties cannot cause individual trial scores to go below 0!

Q&A Session Scoring

- We will ask you to show us a picture of your configuration space (print or digital). This will be worth 5 points.
- We will ask 3 questions about your implementation and about challenges you faced. All group members should be aware of each part of your final solution! The TAs will choose who answers each question. This will be 25 points total.

Video Submission

- This is optional. You can get up to 50% credit of the total 70pts (or 80pts) for the actual demo (not including questions).
- This is due 11:59pm on Tuesday, 16th April 2024.
- Submission Google Form
- Points set for video: Point A: (3, 2)
Point B: (0, 4)
Point C: (-3, 2)
- Clearly show the distance between the end effector and the target point.
- Clearly display valid planned path in software
- Clearly show a timer in your video.

Tips and Tricks

- Make your robot arm as rigid as possible to improve accuracy.
- Gear down the arm motors to increase precision if desired.
- If things are going wrong, think about changing your mechanical design, not just your code.
- Remember to check all configurations generated by inverse kinematics. Some of the configurations may not be reachable under the existence of the obstacle and the boundaries of workspace.
- Make sure to pad your configuration space to avoid obstacles.
- Remember to allow for angle wrap around in your configuration space.
- Be careful of your joint limits, some points may need a full range of motion to be reached.
- BP.set_motor_position(BP.PORT_A, degrees) is incredibly useful.
- In getting started, each team can begin working in parallel on building the arm and generating the configuration space in software.

Getting Started

- Map out your robot's discrete configuration space (theta1,theta2 coordinate) - 10 degree increment.
- Make sure to include bloated obstacles.
- Write a function that will perform inverse kinematic calculations to convert your robot's position into a set of joint angles.
- Follow steps similar to Lab 5 by using path planning.

Links

Link to Rubric: link
Link to Video Submissions: link
Link to Demo signups: link