1 Objective

For the final, your task is to develop a method for the SRV-1 robot to obtain estimates of its position in a world coordinate frame with respect to two landmarks. Specifically, the two landmarks will consist of two color pillars whose world coordinates are known a priori. The individual parts of this final project are outlined below.

1.1 Summary of Tasks

For your benefit, a brief description of the various tasks will be outlined in this section. You can use the following task breakdown as a guideline for allocating responsibilities among your team members. This can also help you in doing a better job of answering your final teamwork questionnaire.

1. Pillar Detection - For this task, you must enable your robot to uniquely identify each pillar based on its color.

2. Centering Controller - This task requires the design of a simple PID controller to enable the robot to center the pillar in its image.

3. Ranging - Once the image is centered, the robot must have the ability to determine its distance from each pillar, which will be denoted by $d_1$ and $d_2$ respectively.

4. Relative Bearing - Then, develop a routine to enable the robot to calculate the angle denoted by $\beta$ in Figure 1.

5. Triangulation - Determine the robot’s position based on the following information $q_{pillar1}$, $q_{pillar2}$, $d_1$, $d_2$, and $\beta$.

6. Kalman Filter - Design a Kalman Filter so as to better estimate the robot’s pose as it moves in the workspace.

7. Demo - Given a starting pose for the robot, $q_s = (x_{rs}, y_{rs}, \theta_{rs})$, and an destination pose $q_d = (x_{rd}, y_{rd}, \theta_{rd})$, develop an open loop controller to drive the robot from the start to the end pose.

2 Task 1 - Pillar Detection

You can use your own color extraction code or the C code provided by the professor to locate each of the pillars. To reliably segment each pillar, you will need to take various images of each pilar from different angles to obtain good color calibration results.
3 Task 2 - Centering Controller

The main objective in this task is to design a controller that will reliably center each pillar in your image. It is good practice to always center each pillar in your image before determining $d_1$ and $d_2$ respectively. Furthermore, a good centering controller will better enable you to determine $\theta$ in Task 4.

4 Task 3 - Ranging

Next, you can use the laser pointers and the code you developed for Assignment 7L to determine $d_1$ and $d_2$. A different option is to take various images of each pillar with the robot at varying distances away from the pillar. Make sure the pillar is always centered in the image. Next, based on this data, find a relationship between the width of the pillar in the image and the distance of the robot to the pillar.
5 Task 4 - Relative Bearing

For this task, consider using your calibration results from the Calibration Lab. Given a turning rate \( \omega \) which you can determine for a particular set of \( m_R = -m_L \), in theory \( \theta = \omega \delta t \) where \( \theta \) denotes the angle the robot has turned and \( \delta t \) denotes the amount time \( \omega \) was applied. To determine \( \theta \) in practice may require you to apply a series of \( \omega_i \) commands, each applied for \( \delta t_i \) seconds, such that \( \theta = \sum \omega_i \delta t_i \) where \( \omega_i \) can be either positive or negative. As such, a good centering controller would be extremely helpful.

6 Task 5 - Triangulate

Now, given your measurements \( d_1, d_2, \) and \( \theta \), you can estimate the robot’s pose, denoted by \((x_r, y_r, \theta_r)\) in the world coordinate frame using some simple trignometry.

7 Task 6 - Kalman Filter

Using the results from your calibration lab, design a Kalman filter to better estimate the robot’s pose. See Assignment 9I.

8 Task 7 - Demo

The day before your demo, you will be given a start and destination pose. When designing your open-loop navigation controller, you may want to consider first navigating to the destination pose. Once at the approximate final configuration, localize. Determine whether the errors are acceptable or not. If no, enable the robot to make adjustments until the errors have become acceptable.

For the Lab Report: Please include the following in your lab report:

- Describe in detail how you designed, integrated, and tested the various components of your system.
- Discuss the problems that you encountered along the way. What do you think contributed to these problems? How did you solve them?
- Discuss why you think the different components of your code work or did not work?
- Include the following results from the demo: 1) estimated initial and final pose; 2) exact initial and final pose.
- Describe methods to improve your system.