EN.530.666 Magnetically Actuated and Magnetic Resonance Compatible Imaging
Lab 2: Magnetic Surgery Lab - Robot Localization

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Spring 2025

Due Date: Friday, February 14, 11:59 PM

February 4, 2025

1 Problem Statement

In this lab assignment, you will learn to develop localization methods for the petri dish and the robot. You will accomplish this by i) performing camera robot calibration by localizing the petri dish, ii) finding and segmenting the robot-aided by Color segmentation, iii) finding and evaluating the actual localization of the robot in metric Cartesian coordinates.

2 Camera Robot Calibration

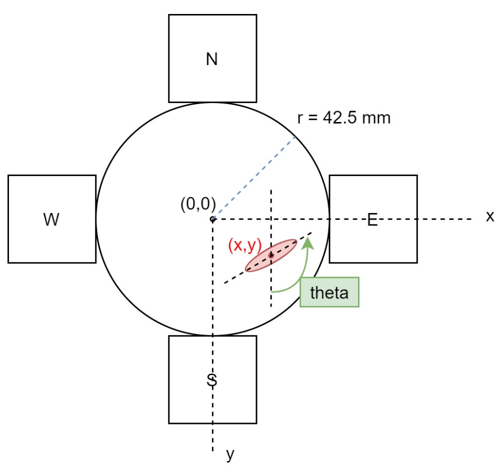

Figure 1: Actual robot coordinates and the physical environment.

In this section, you will find the petri dish by using the overhead camera and MATLAB built-in functions. The overhead camera will only give you the pixel coordinates of the robot with the origin at the top left corner of the image. The robot coordinate system's center is at the petri dish's center. Therefore, you need to localize the petri dish to convert the robot location in image coordinates (pixels) into robot coordinates (meters). In findPetri.m, you will first convert the image into binary with a threshold and then use the built-in Hough-based circle finder imfindcircles() to find the circle on the image. Please refer to resources and lecture notes to understand the function imfindcircles(). You are also free to choose any Computer Vision algorithm of your choice as long as you do not change the input and output to the "findPetri.m" function. To make the debugging and tuning easier for this section and the next section, you can use 'Image Acquisition' under APPS and capture an image frame for image processing, this will allow you to process the image while not needing the system. At the end of this section, you should be able to return the correct petri dish center and radius. Use the petri diameter in pixels and the actual petri dish diameter (85mm) to calculate the converting scalar between the pixel coordinates and the robot coordinates. Take a screenshot of the binary image and the thresholded image. Once you run the main script, you should see a circle overlapping with the edge of the petri dish. Take a screenshot of this as well. To verify your camera robot calibration, you will find the error between the actual center of the petri dish (indicated with a small marker at the center of the physical petri dish) and the calculated center of the petri dish. Calculate the error in pixels.

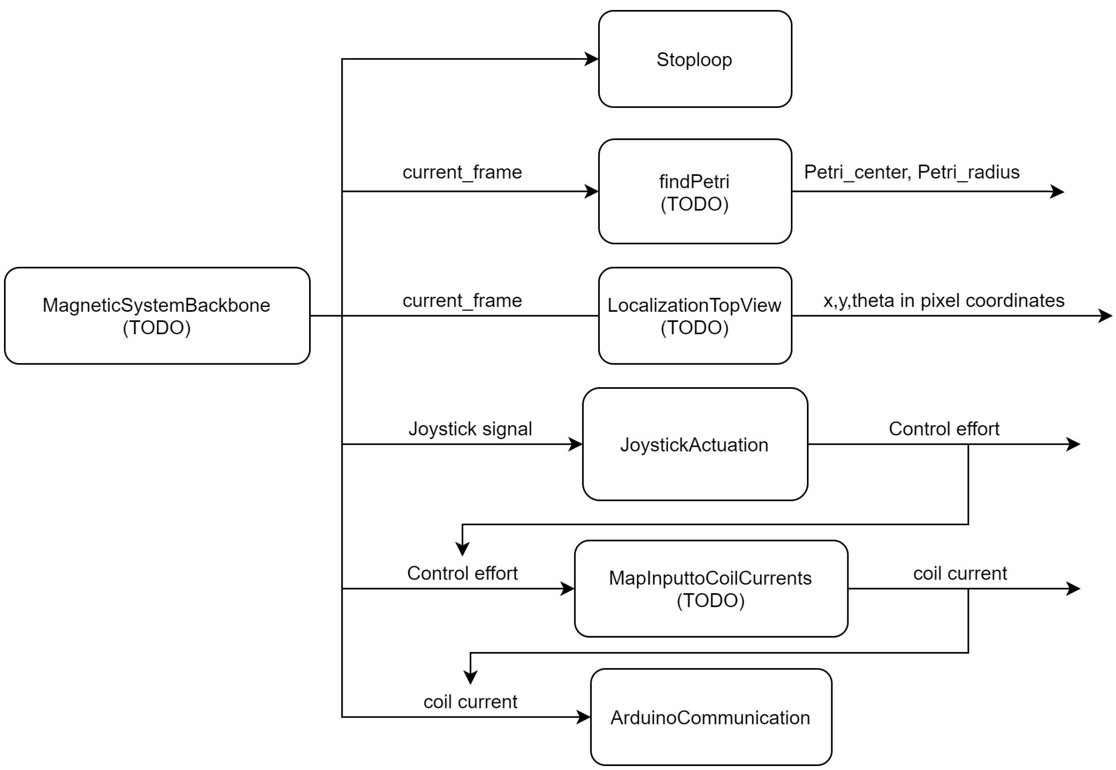

Figure 2: Schematic of functions of lab2.

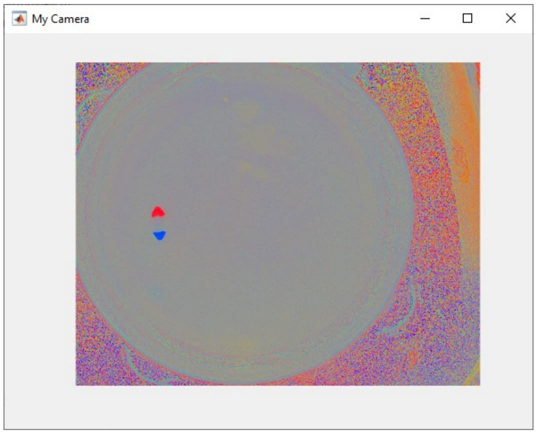

Figure 3: Normalized image.

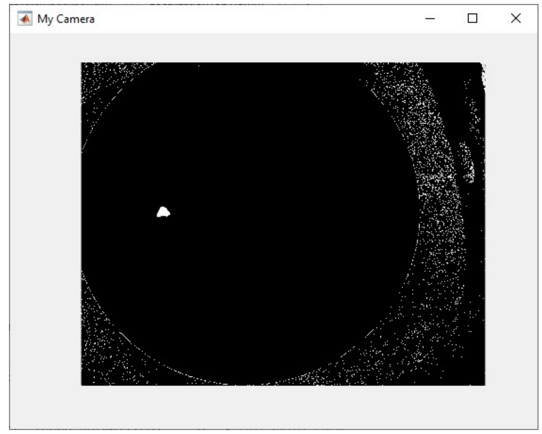

Figure 4: Red regions on the image.

3 Find and Segment the Robot with Color Detection

In this section, you will localize your robot with color detection. Figure 1 shows you the dimension and definition of the robot coordinate system. As mentioned in the lectures, you need to decide how you want to localize your robot and find its orientations. The robot example from the previous lab used red and blue colors. The color detection will find the coordinates for the red and blue and use the midpoint of the two points to represent the robot coordinate. The line connecting these two points will be used to determine the robot's orientation. Use the HSV threshold method mentioned in the localization lecture and finish LocalizationTopView.m. Once you are done with LocalizationTopView, turn on Localization in our backbone script and uncomment the section for Markers. You should see a yellow dot following your robot and a brown line representing the orientation as you move the robot. Turn on videoRecording in your scrips and record a 30 seconds video. Processing time is critical for closed-loop control. You will also use tic and toc to find the processing time of your localization function. Take the average of 20 processing times of the recorded images and also find and report the standard deviations of these processing times.

4 Find Actual Location of the Robot

In this section, you will convert the camera pixel coordinates into metric robot coordinates. The camera almost aligns with the center of the petri dish and we assumed the center of petri dish as the origin of the robot coordinate. You will find the relationship between the pixel coordinates and robot coordinates in meter/pixel. Record your actual robot coordinates and orientation in real time (x,y,theta) while you are moving the robot with a joystick (You should save it to 'experimentdata'). Make a plot of x and y (in robot coordinate) vs time. Use a short line to represent the robot's orientation in the camera image. You should also record the robot location and orientation in pixel coordinates in 'experimentdata'. In the end, you should be able to generate a plot that presents the pixel coordinates of the robot at each frame on the image you captured. You can use imtool() to locate the robot in pixel coordinates and estimate the actual location of the robot. Record a video of your moving robot controlled with your joystick with at least 20 sets of points. Compare the robot coordinates generated by your localization function with a) the coordinates estimated with imtool() and calculate the error of robot camera calibration, and b) with using a manual segmentation of your markers to localize your robot. You can use the function ginput to manually select your markers' positions.

5 Resources

- Introduction to Magnetic System
- Remove small object from binary image
- Measure properties of image region
- Find circles using circular Hough transform

6 Helpful notes

The homework file contains multiple code files, which might make it challenging to determine where to start. However, you are not required to read and understand all of them. The best approach to completing the MATLAB code is to begin with MagneticSystemBackbone.m. Use "Ctrl+F" to search for "TODO" and follow the provided instructions. If the TODO directive refers to another function file, open it and complete the required code accordingly.

7 Submission

A zip file per project team (100 points) containing the following items:

1. A single PDF file per project team with a short lab report containing a summary of the lab with the following items:
   - How did you localize the petri dish? (10 points)
   - How did you localize your robot? (10 points)
   - Error of camera robot calibration (20 points)
   - Error analysis of localization and computation time (20 points)
   - Summary and discussion for all the videos and plots (10 points)
2. A video showing localization working (with a marker representing the robot location and a line representing the orientation) (10 points)
3. A plot of the actual robot path with x, y, and theta in robot coordinates (20 points)
4. A zip file containing all your MATLAB scripts (Required to receive a grade for this assignment)