Control of Mobile Robotics

CDA4621

Spring 2023

Lab 5

Localization

Total: 100 points

Due Date: 4-3-2023 by 11:59pm

The assignment is organized according to the following sections: (A) Requirements, (B) Objective, (C) Task Description, (D) Task Evaluation, and (E) Lab Submission.

A. Requirements

A.1 Physical Robot

Robot: "Robobulls-2018". **Programming**: Python

A.2 Robot Simulator

Simulator: Webots. **Robot**: "e-puck". **Programming**: Python
Basic Files: "Lab5_epuck.zip"

B. Objective

This lab will teach you about probabilistic robot localization using motor control, sensors, and camera, from the previous labs. Do not modify the world, nor add any new devices to the robot, or modify sensor or camera configurations from those already given.

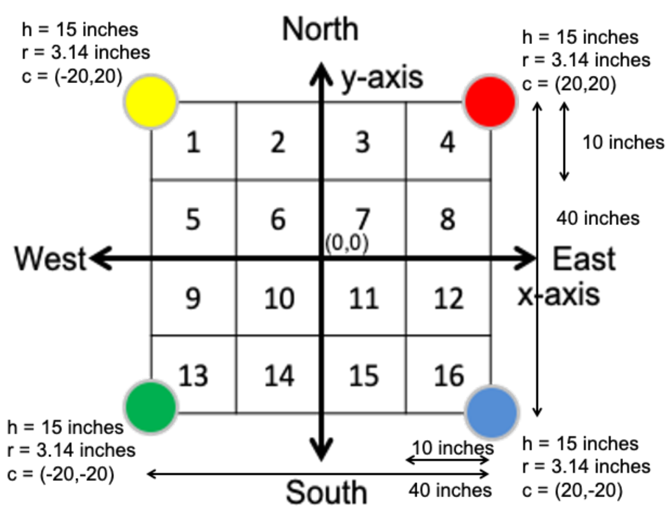

Figure 1. Global reference frame and grid cell numbering scheme.

B.1 Global Reference Frame and Grid Cell Numbering

The global reference frame and grid cell numbering scheme is shown in Figure 1. The positive y-axis points North while the negative y-axis points South. The positive x-axis points East while the negative x-axis points West. Origin (0,0) is in the middle of the arena. The arena consists of 16 grid cells, numbered 1-16, each measuring 10 x 10 inches. There are four colored cylinders (yellow, red, blue & green) located in the corners of the arena, having the same fixed size (radius "r" = 3.14 inches, height "h" = 15 inches), and centered "c" at the corners of the grid.

B.2 World Configurations

Two world configurations are shown in Figure 2.

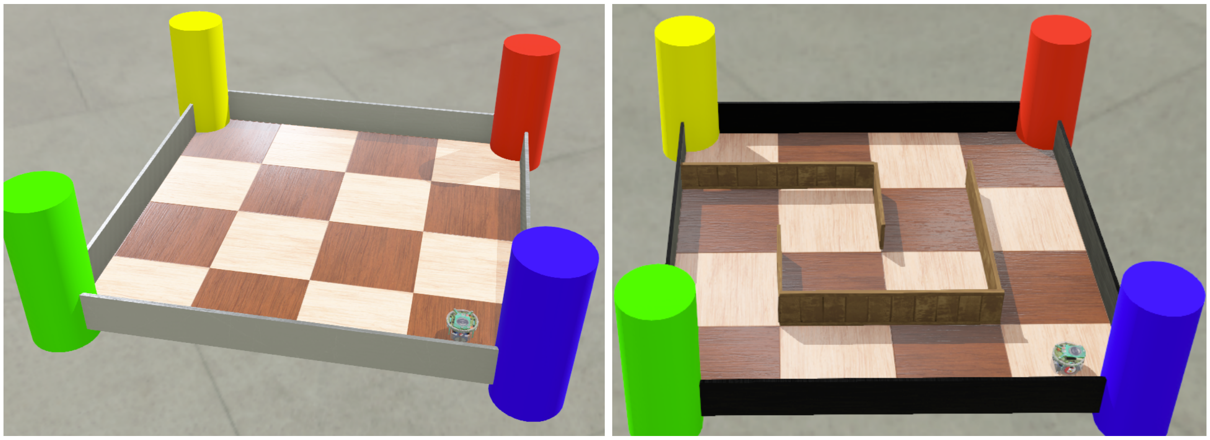

Figure 2. (Left) World with colored landmarks. (Right) World with colored landmarks and internal walls.

B.3 Pose (State) Printing

In all tasks you need to print the following information (once per cell):

(a) Visited cells. Use as an example the table below to display already visited cells, where an "X" indicates a visited cell, and "." indicates a yet to be visited cell. Top left corner corresponds to cell number "1" as described to Figure 1.

```
....
XXX.
XXX.
X...
```

(b) Robot pose (state). State is given by $s=(x, y, n, \theta)$, where "x,y" represents the robot position in global coordinates, "n" represents the grid cell number, and "θ" represents the robot global orientation with respect to the global frame of reference.

C. Task Description

The lab consists of the following tasks:

- Task 1 – Localization from Motion Estimation ("Lab5_Task1.py")
- Task 2 – Localization from Measurement Estimation ("Lab5_Task2.py")
- Task 3 (Extra Credit) – Localization with Particle Filters ("Lab5_Task3.py")

C.1 Task 1 – Localization from Motion Estimation

Localization from motion estimation requires keeping track of robot pose based exclusively on encoders and IMU readings without using cameras. Robot may use distance sensors to avoid hitting walls. Robot may follow any desired path starting from a known initial pose specified by the TA. The robot should end task when all grid cells have been navigated, or after 3 minutes. Print the estimated pose every time the robot enters a new grid cell. Test with both worlds.

C.2 Task 2 – Localization from Measurement Estimation

Localization from measurement estimation requires keeping track of robot pose based on triangulation or trilateration algorithms, using cameras and any other of its sensors. The robot may follow any desired path starting from an unknown initial pose specified by the TA. The robot should end task when all grid cells have been navigated, or after 3 minutes. Print the estimated pose every time the robot enters a new grid cell. Test with both worlds.

C.3 Task 3 –Localization with Particle Filters (Extra Credit)

Localization with particle filters requires keeping track of robot pose based on using measurements to walls, and optionally to cylinders, using camera and any other of its sensors. The robot may follow any desired path starting from an unknown initial pose specified by the TA. The robot should end task when all grid cells have been navigated, or after 3 minutes. Print the estimated pose every time the robot enters a new grid cell. Test with both worlds.

D. Task Evaluation

Task evaluation is based on: (1) program code, (2) report, including a link to a video showing each different task, and (3) task presentation of robot navigation with the TA. Note that all functions and tasks to be implemented are required in future labs.

D.1 Task Presentation (90 points)

The following section shows the rubric for the tasks shown in the video:

- Task 1 (45 points)
  - Prints correct information from all cells using motion estimation (20 points)
  - Keeps track of X and Y coordinates within a range of 3 inches (10 points)
  - Keeps track of robot’s current cell (10 points)
  - Navigates to all cells in grid (5 points)
  - Prints sensor information at each timestep (-5 points)
  - Robot hits walls (-5 points)
- Task 2 (45 points)
  - Prints correct information for all cells using measurement estimation (20 points)
  - Keeps track of X and Y coordinates within a range of 3 inches (10 points)
  - Keeps track of robot’s current cell (10 points)
  - Navigates to all cells in grid (5 points)
  - Prints sensor information at each timestep (-5 points)
  - Robot hits walls (-5 points)
- Task 3 (45 points)
  - Prints correct information for all cells using measurement estimation (20 points)
  - Keeps track of X and Y coordinates within a range of 3 inches (10 points)
  - Keeps track of robot’s current cell (10 points)
  - Navigates to all cells in grid (5 points)
  - Prints sensor information at each timestep (-5 points)
  - Robot hits walls (-5 points)

D.2 Task Report (10 Points)

The report should include the following (points will be taken off if anything is missing):

1. Mathematical computations for all kinematics. Show how you calculated the speeds of the left and right servos given the input parameters for each task. Also, show how you decide whether the movement is possible or not. (4 point)
2. Video uploaded to Canvas showing the robot executing the different tasks. You should include in the video a description, written or voice, of each task. You can have a single or multiple videos. Note that videos will help assist task evaluations. (3 point)
3. Conclusions where you analyze any issues you encountered when running the tasks and how these could be improved. Conclusions need to show an insight of what the group has learnt (if anything) during the project. Phrases such as “everything worked as expected” or “I enjoyed the project” will not count as conclusions. (3 point)

D.3 Task Presentation

Task presentation needs to be scheduled with the TA. Close to the project due date, a timetable will be made available online to select a schedule on a first come first serve basis. Students must be present at their scheduled presentation time. On the presentation day, questions related to the project will be asked, and the robot's task performance will be evaluated. If it is seen that any presenter has not understood a significant portion of the completed work, points will be deducted up to total lab points. Students that do not schedule and attend presentations will get an automatic "0" for the lab.

NOTE for physical robot presentation: During presentations, robot calibration time is limited to 1 min. It is important that all members of the team attend and understand the work submitted.

E. Lab Submission

Each student needs to submit the programs and report through Canvas as a single "zip" file.

- The "zip" file should be named "yourname_studentidnumber_labnumber.zip"
- Videos should be uploaded to the media folder in Canvas. Name your files "yourname_studentidnumber_labnumber_tasknumber".
- The programs should start from a main folder and contain subfolders for each task.
- The report should be in PDF and should be stored in the same "zip" file as the programs.