Control of Mobile Robotics
CDA4621
Spring 2023
Lab 6
Mapping & Path Planning
Total: 100 points
Due Date: 4-17-2023 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: "Lab6_epuck.zip"

B. Objective

This lab will teach you about robot mapping and path planning. Do not add any new devices to the robot or modify sensor or camera configurations from those already given.

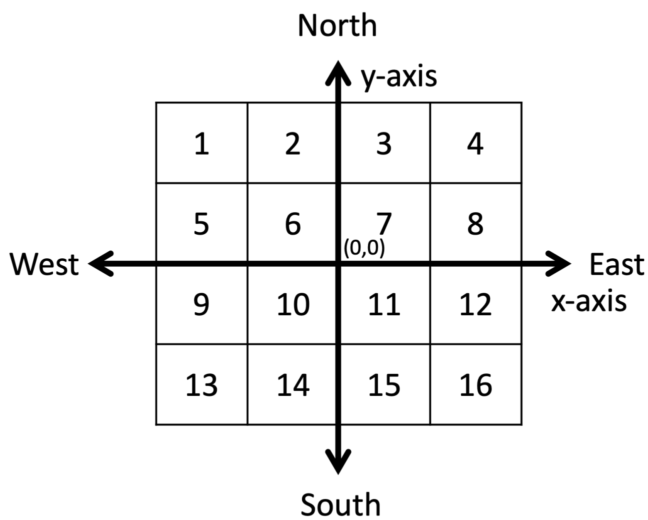


Figure 1. Global reference frame and grid cell numbering scheme.

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.

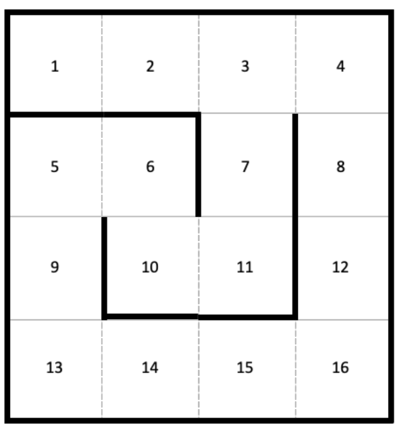
B.2 World Configurations

Three different world configurations with internal walls are shown in Figure 2.

Figure 2. Three different Webots world configurations with internal worlds.

B.3 World Representation

You will need to represent the world internally in your program using any desired data structure. You can use a 16x4 matrix or linked list representation for world configurations, as shown in Figure 3. For example, the world in Figure 3 (left) may be represented by the table in Figure 3 (right) showing the global West-North-East-South (WNES) wall representation, where "W" represents "Wall", and "O" represents "No Wall".



Cell	Walls (WNES)
1	WWOW
2	OWOW
3	OWOO
4	OWWO
5	WWOO
6	OWWO
7	WOWO
8	WOWO
9	WOWO
10	WOOW
11	OOWW
12	WOWO
13	WOOW
14	OWOW
15	OWOW
16	OOWW

Figure 3. (Left) Wall configuration and (Right) corresponding wall representation using a 16x4 matrix configuration describing the 16 cells, and 4 walls organized as West-North-East-South (WNES), where "W" represents "Wall", and "O" represents "No Wall".

B.4 Pose (State) Printing

For 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 – Wall Mapping ("Lab6_Task1.py")
- Task 2 – Path Planning ("Lab6_Task2.py")

C.1 Task 1 – Wall Mapping

Mapping requires dynamically finding the complete internal wall configuration of the maze. Robot may follow any desired path and should end the task when all grid cells have been navigated, or after 3 minutes. The robot can go through grid cells multiple times. Print the map information every time the robot enters a new grid cell. Mapping task will be performed twice, with robot starting from two different initial states: (a) start from a known grid cell "16" oriented "North", and (b) start from an unknown location and orientation (given by the TA only at the start of the evaluation). Test with the three worlds.

C.2 Task 2 – Path Planning

Path planning requires finding and navigating the shortest path between a start and goal location. For this task, the map and end goal location will be specified by the TA prior to program execution (end goal orientation is not important). For path planning you should use the wavefront planner with 4-point connectivity. The robot should end task when all grid cells have been navigated, or after 3 minutes. The robot may travel through grid cells multiple times. Prior to navigation, print the entire planned path. During navigation, the robot needs to print its current location. At the goal, the robot should stop and print "GOAL". Path planning task will be performed twice, with robot starting from two different initial states: (a) start from a known grid cell "16" oriented "North", and (b) start from an unknown location and orientation (given by the TA only at the start of the run). Do not hardcode the path to be followed by the robot. Test with the three worlds.

D. Task Evaluation

Task evaluation involves: (1) programs, each task as a different controller, and (2) report, including links to a video showing each different task. Points will be taken off for any robot that crashes into walls or gets stuck in any way. Note that the TA will be testing the different tasks under slightly different mazes to evaluate your solutions.

D.1 Task Presentation (90 points)

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

- Task 1 (45 points)
    - Robot correctly maps each grid for the entire maze from known initial starting and ending location (20 points)
    - Robot correctly maps each grid for the entire maze from unknown initial starting and ending location (20 points)
    - Prints correct information at each timestep (5 points)
    - Robot hits walls (-5 points)
    - Robot cannot complete task under 3 minutes (-5 points)
- Task 2 (45 points)
    - Robot computes correct shortest path to the goal from known initial starting and ending location (10 points)
    - Robot computes correct shortest path to the goal from unknown initial starting and ending location (10 points)
    - Robot travels correct shortest path to the goal from known initial starting and ending location (10 points)
    - Robot travels correct shortest path to the goal from unknown initial starting and ending location (10 points)
    - Prints correct information at each timestep (5 points)
    - Robot hits walls (-5 points)

- Robot cannot complete task under 3 minutes (-5 points)

NOTE: Do not make calls to print statements inside the “while” loop or functions called from the “while” loop more than once per cell (do not print at each time step). Otherwise, you will be penalized up to 15% of your lab grade. You may have print statements outside the “while” loop.

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. <u>Students that do not schedule and attend presentations will get an automatic “0” for the lab.</u>

<u>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.</u>

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.