*Chapter 45*

# *The Gauntlet*

## *45.1 Overview*

You have mastered the Bridge of Doom and navigated Flatland. Now you face the most challenging challenge you've ever been challenged with. In this final challenge, you will help your robot to dodge through obstacles on your way to the ultimate prize – knowledge.

Throughout this semester, you have applied many quantitative engineering analysis tools. For this challenge, you'll use a powerful new sensor (the laser scanner), explore some algorithms for optimization, and use the mathematics of potential functions and vector fields.

If you'd like you can work in a group (up to 3 people total per group) to complete the challenge and the write-up.

**Learning Objectives**

This challenge has varying levels of difficulty. The learning objectives vary based on the level you choose.

1. Fit models of lines and circles to laser scan data (level 2 and 3).
2. Implement outlier resistant optimization via the RANSAC algorithm (level 2 and 3).
3. Create suitable potential functions and vector fields to guid a robot to a goal while avoiding obstacles (all levels)
4. Transforming between multiple coordinate systems (all levels)

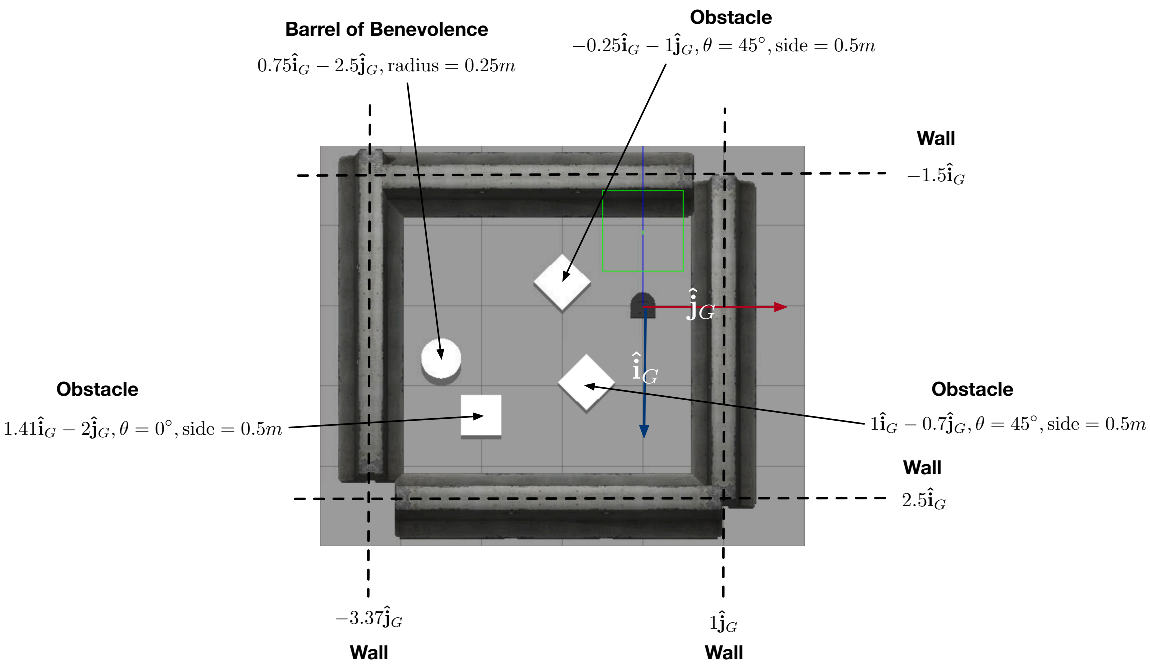


Figure 45.1: A top-down view of The Gauntlet. You should write a program to guide the Neato past the obstacles (boxes) to the goal (the Barrel of Benevolence).

## *45.2 The Challenge*

Your goal is to write a program to pilot your (virtual) Neato through a series of obstacles (concrete barriers and boxes). You will detect these obstacles using your robot's onboard laser scanner, which can detect obstacles within a 5m range (see Figure 45.1).

This final QEA-I challenge has a hierarchy of missions, which get progressively more difficult. For all missions, the goal is to gently tap the Barrel of Benevolence (BoB). For all missions, the Neato starts at coordinate $0\ m\hat{\mathbf{i}} + 0\ m\hat{\mathbf{j}}$, facing along the $+\hat{\mathbf{i}}$ direction.

Here are the conditions for the missions:

Level 1 You are given the coordinates of the BoB and the obstacle and wall locations (see Figure 45.1). You will use these locations to create a potential field and use gradient descent to move your robot through the Gauntlet to the BoB. The path can be entirely pre-planned.

Level 2 You tackle the same challenge as level 1, but you must use the LIDAR to detect and avoid obstacles (i.e., you should not use the obstacle and wall locations in Figure 45.1, but instead determine them from the robot's sensors). You can plan your entire path based on your initial LIDAR scan or dynamically update your path as you go.

Level 3 You tackle the same challenge as level 2, but you are given the radius of the BoB (see Figure 45.1), but not the coordinates (i.e., you must use LIDAR scans to identify and locate the BoB). You can plan your entire path based on your initial LIDAR scan or dynamically update your path as you go. To identify the BoB, you will need to differentiate the distinctive, circular shape of the goal from the linear shape of the obstacles. If you choose this mission, we recommend you look at the circle-fitting extension at the end of Day 9 for guidance.

To achieve whichever mission(s) you choose to accept, you will apply what you have learned about potential functions and vector fields. You may also choose to extend any of the above missions by applying or creating another goal-seeking/obstacle-avoiding algorithm, not taking the BoB's radius as an input, or trying to reach the target as soon as possible.

### *Loading the Gauntlet*

Before starting the challenge, refresh your QEA robot software using the following command in Powershell (this will update the Gauntlet world).

```
docker pull qeacourse/robodocker:spring2020
```

In order to load the Gauntlet simulation, use the following Docker command. Once the simulator is up and running, you can program the robot as before in MATLAB.

```
docker stop neato; docker rm --force neato; docker run --rm --name=neato --sysctl
    net.ipv4.ip_local_port_range="32401 32767" -p 11311:11311 -p 8080:8080 -p
    32401-32767:32401-32767 -e NEATO_WORLD=gauntlet_final -it
    qeacourse/robodocker:spring2020
```

## *45.3 Deliverables*

Don't think of these deliverables as only items to check off, but rather think of them as scaffolding to get maximum learning from the task at hand. By creating these intermediate deliverables, you will be able to more easily debug your code as well as your understanding of the algorithms you are utilizing.
**Note that all of these deliverables can be done with your group (if you are working with others for the challenge). Make sure to clearly specify who is in your group for the challenge on each deliverable. Unless otherwise noted, the components are required for all levels of the challenge.**

**Mapping and Path Planning (due 5/7, but suggested completion date is 5/4) [6 pts]:** We suggest that you make significant progress on the math side of this project before class on Monday. Create a document with the following plots:

1. A map of the pen, collected from a single LIDAR scan obtained from the robot's initial position, with walls and obstacles fitted as line segments using your RANSAC algorithm (levels 2 and 3). A fit for the BoB (level 3). [2 pts]

2. An equation and a contour (or 3-D) plot of the potential field you developed for the pen. The potential field can be based on the given features in Figure 45.1 (level 1) or based on a LIDAR scan from the robot's initial position (levels 2 and 3). [2 pts]

3. A quiver plot of the gradient of your potential field. [1 pt]

4. A path of gradient descent from the starting point to the BoB. [1 pt]

These plots should be clearly labeled and readable (decent size fonts!). **You will turn these in on Canvas through the Mapping and Path Planning assignment.**

**Navigating the Gauntlet (due 5/7) [8 pts]:** Prepare a video and a **brief** writeup of your work on this challenge.
Your final writeup should center around critical information and informative figures. It can be as short as you want, but it must contain the following components:

1. A short introduction stating the mission you chose and a brief summary of the strategy you used to solve the challenge. You might find it helpful to refer to the decomposition exercise from Day 9. [1 pt]
2. Some experimental data that shows, quantitatively, how well your system worked, plus a few sentences of explanation. Note: you could make use of the collectDataset_sim.m function for this.
   a) The time it took your robot to get to the BoB (for whichever mission you choose) and the distance it traveled. [1 pt]
   b) A plot with: a map of the relevant features of the Gauntlet based on a LIDAR scan (levels 2 and 3) or the features given in Figure 45.1 (level 1), the intended path of gradient descent, and the path your robot took calculated from the wheel encoder data. This should be a legible plot with axis labels, a legend, and a caption...the works. [3 pts]
3. A link to a video of your robot in action. [2 pts]

In addition to the writeup, you should also turn in your (commented and readable!) code. [1 pt]