# The Gauntlet Report

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## Introduction

The Gauntlet: a truly epic and treacherous journey that all NEATOs would hesitate to endure. It is the goal of any NEATO in their lifetime span to reach the Barrel of Benevolence, a barrel which contains the materials needed for NEATO enlightenment. However, this would mean that a NEATO would have to be dropped in a random location of this enclosure, which includes many obstacles along the way, and bumping into any one of these or the wall certainly implies instant death. After crossing the Bridge of Doom, our robot "Devon" now needs to endure this final epic journey to discover the true meaning of what it means to be a NEATO. However, with the whole human race wiped out, he will have to rely on the program that was uploaded to him before a meteor struck Earth. Can he do it?

The mission chosen for this Gauntlet mission was Level 2. Before people was wiped out, Sushmit and Neel were able to discover this Gauntlet and pinpoint where the Barrel of Benevolence was. However, they were not able to pinpoint any obstacles inside the Gauntlet or even the walls. Luckily, Devon has a LIDAR scanner that can be used to detect the obstacles. The two programmers decided to first drop their NEATO in various locations of the Gauntlet to create scans of the interior. These scans were then compiled together to generate a map of what the Gauntlet would look like. They then removed the Barrel of Benevolence from this map. Next, RANSAC was used to create lines which defined the walls of the Gauntlet and the obstacles. Along these lines, endpoints were created and defined as sources. The Barrel was redrawn back into the Gauntlet as a series of points, which were defined as sinks. A contour plot can be derived from this information. Finally, from its starting location, Devon would use gradient decent to find an ideal way to navigate to the Barrel of Benevolence.

## Preparation

Firstly, the interior of the Gauntlet was mapped out so that the Neato can learn how to find the BoB, as well as identify the obstacles in the way and the walls. Using the given coordinate system, we defined four different points in the gauntlet as "Top Left, Top Right, Bottom Left, Bottom Right." Figure 1 shows the initial scans of the Neato's LiDAR sensor at these corners of the plane. To be more specific, the points for our corners were at (-0.7, 0.3), (1.8, 0.3), (1.8, -2.5), and (-0.7, -2.5), respectively. Note that these points are defined by the Gauntlet coordinate plane and not the Neato plane. Each LIDAR scan then must be translated into the Gauntlet plane since the Neato sees itself as the origin of the plane when making a scan. (Very self-centered, honestly.) Figure 2 shows the scans compiled onto the same plane.

**Figure 1: LIDAR scans taken at four corners of gauntlet**

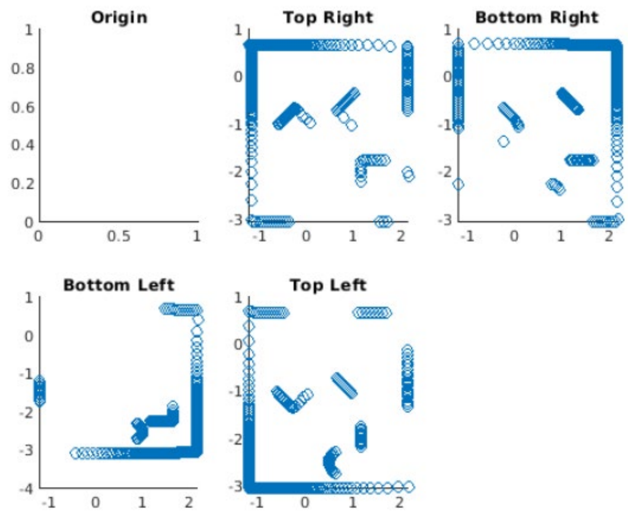
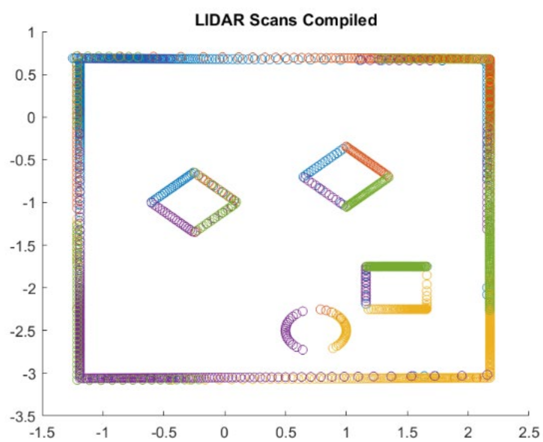


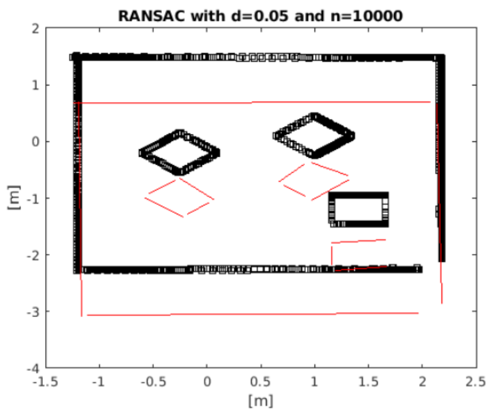

**Figure 2: LIDAR scans compiled in one plane**




Since the mission we chose included the utilization of the RANSAC function, we had to alter our data to make it usable. The main changes were having to remove the data points for the BoB because RANSAC cannot run on circles, converting everything to polar coordinates. After configurating it to work on our data, we ran the function and found the plot below.

To use RANSAC, the points for the Barrel of Benevolence were removed, since RANSAC cannot create circular shapes. Since the algorithm can only create lines, it will be able to reproduce the obstacles and walls. Figure 3 shows the results of the RANSAC. Since the gauntlet plane and the Neato's plane are offset from each other by 0.8 meters in the y-direction, the endpoints used to create the lines (in red) were translated by -0.8 meters in the y-direction.

**Figure 3: RANSAC**




## Potential Field

With the endpoints from RANSAC, Devon's programmers were able to develop the contour field of the gauntlet environment and the gradient field necessary for the Neato to follow. They used those endpoints to create x and y "linspaces" to represent every line depicted in Figure 3. Looping through these "linspaces", they applied two equations to each point, where $V$ is the potential field at that point, and $\nabla V$ is the gradient field at that point.

$$V(x, y) = V + \ln\sqrt{(x-a)^2 + (y-b)^2}$$

$$\nabla V = \frac{x-a}{(x-a)^2 + (y-b)^2} i + \frac{y-b}{(x-a)^2 + (y-b)^2} j$$

Above, *x* and *y* are mesh grids defined in the MATLAB program, and *a* and *b* represent the x- and y-coordinates for these endpoints. Both these equations set the points as sources. Once the Barrel of Benevolence was drawn back into the plane, those points were set as sources by using negative of the above equations. Figure 4 shows the resulting contour plot.

**Figure 4: Contour Plot**

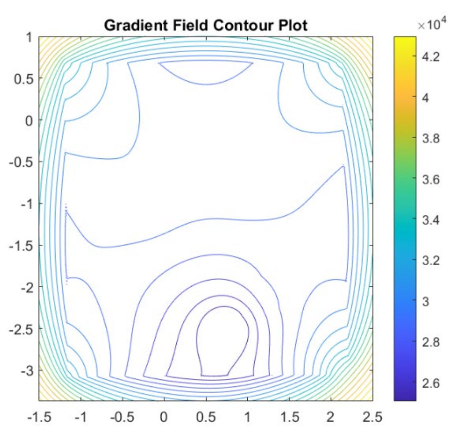
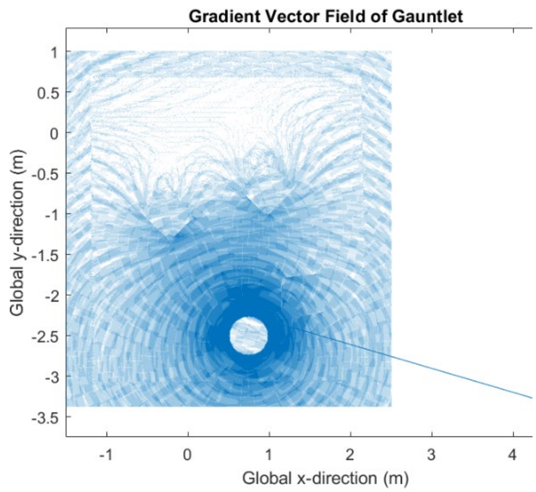


**Figure 5: Gradient Vector Field**




Within the gradient field, the sources and the sinks had to be weighted differently to ensure that the Neato would follow an ideal path away from the obstacles and walls and towards the Barrel of Benevolence. The source points were weighted with a factor of 100, and the walls were weighted with a factor of 2. Figure 5 shows the resulting vector field. Note how the vectors are very concentrated at the barrel.

## Gradient Descent

Gradient descent was run for the Neato on the gradient field vectors that were calculated above. Gradient descent is calculated using the following formula.

$$r_{i+1} = r_i - \lambda_i \nabla f(r_i)$$

In this formula, *i* is an integer that starts at 0 and continues to increase by one, and $r_i$ is the *i*'th position vector as the Neato moves along, where $r_0$ is the Neato's initial position. The second half of the equation is what determines what the next position vector will be, since $\nabla f(r_i)$ is the gradient vector at $r_i$ and $\lambda_i$ is a constant representing the size of each step. Figure 6 shows the contour plot with the gradient descent path, where Devon starts at the origin.

These position vectors were stored in a matrix called *R*. Once opened in a simulator environment, Devon referenced *R* to know where to go. During the simulation, our robot took about 45 seconds from when it started moving to when it hit the Barrel. Figure 7 shows the data from Devon's left and right wheels.

**Figure 6: Contour Plot with Gradient Descent (Neato starts at origin)**

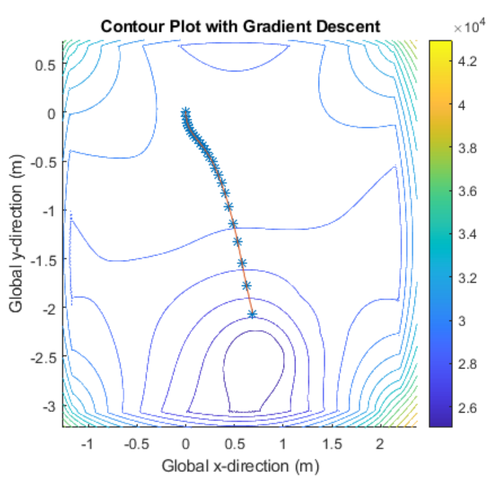
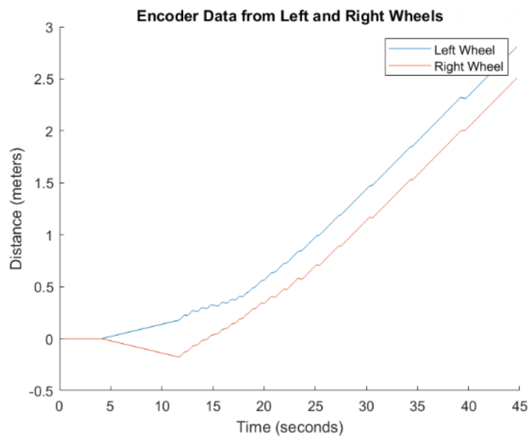


**Figure 7: Wheel distances over time**




## Conclusion

In short, Devon was able to reach the end of his long and treacherous journey. On looking into the Barrel of Benevolence, he discovers a program file that allows him to gain the knowledge in starting the Neato race. The link to the video of Devon's journey and the link to the MATLAB code that helped him go is down below.

Overall, the system worked well. While the Neato made it through the path relatively slowly, it avoided all obstacles and took a straight and direct path towards the barrel. The Neato could have stopped sooner, as it did push the barrel forward slightly before the simulation ended.

Devon's Gauntlet Journey: (1) Devon the Neato Encounters Gauntlet - YouTube

Devon's Program Files: https://drive.matlab.com/sharing/31331f97-ba84-4686-94fe-8eeb212ed3f3