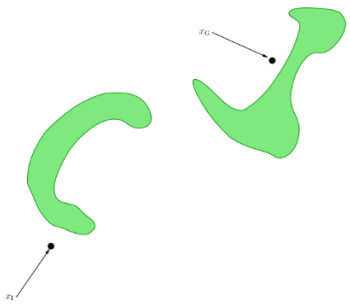
# Homework 5

Mu-Ruei Tseng

September 10, 2024

## 1 Question 1

Your mobile robot wants to travel from $x_I$ to $x_G$ in the environment below.




1. Show the path that would be followed if the robot executed the **Bug1** algorithm for this navigation task. Draw neatly, especially if the path overlaps itself so that your answer is unambiguous. Label the hit points as $H_1, H_2, ...$ and the leave points as $L_1, L_2, ....$
2. Show the path that would be followed if the robot executed the **Bug2** algorithm for this navigation task. Draw neatly, especially if the path overlaps itself so that your answer is unambiguous. Label the hit points as $H_1, H_2, ...$ and the leave points as $L_1, L_2, ....$

### 1.1 Solution

#### 1.1.1 Bug1 Algorithm

Bug 1 algorithm can be broken down into 4 steps:

1. Move toward the goal until reaching an obstacle.
2. Turn left and follow the obstacle boundary. Keep track of which point on the boundary is closest to the goal.
3. Return to this point, following the obstacle boundary in whichever direction is shorter.
4. Repeat to 1. until the robot reaches the goal.

To illustrate, we introduce several notations:

- $H_i$: The Hit point to obstacle $i$.

- $L_i$: The Leave point, i.e. the point on the obstacle $i$ boundary that is closest to $x_G$
- $d_i^L$: The distance traveled when making a left turn at point $H_i$ to travel to $L_i$.
- $d_i^R$: The distance traveled when making a right turn at point $H_i$ travel to $L_i$.

Figure 1 shows the navigation when we hit the first obstacle. Here is a step-by-step breakdown:

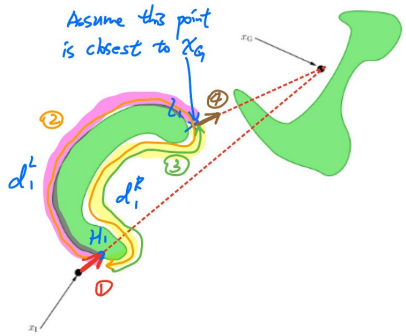



Figure 1: When the robot encounters the first obstacle. The number indicates the path sequence that the robot takes.

The robot first follows the shortest available path from $x_I$ to $H_G$ and reaches obstacle 1 at $H_1$. It then travels around obstacle 1 and records that the closest point on the boundary of obstacle 1 to $x_G$ is at $L_1$. The robot returns back to $H_1$ and knows that $d_1^L > d_1^R$. Therefore, the robot turns right to travel back to $L_1$ and leaves obstacle 1 in a direction that is closest to $x_G$.

The robot will next encounter obstacle 2, see Figure 5

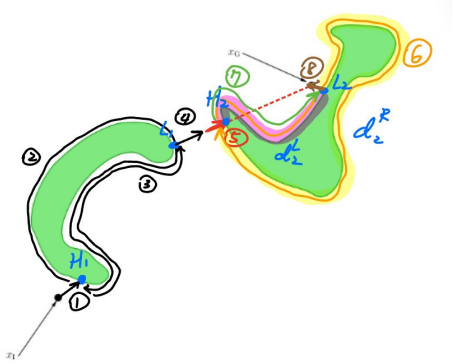



Figure 2: When the robot encounters the second obstacle.

Similar to the situation when the robot meets obstacle 1, it first travels the shortest available path to $H_G$ until reaching the obstacle at $H_2$. The robots then turn left and travel around the obstacle until reaching back to $H_2$ while tracking the closest point to the goal ($L2$). After coming back to $H_2$, it knows that $d_2^L < d_2^R$ and turns left to travel to $L_2$. The robot leaves at $L_2$ and can directly reach the goal $x_G$.

The robot's full route to travel from $x_I$ to $x_G$ using the Bug1 algorithm is shown in Figure 3.

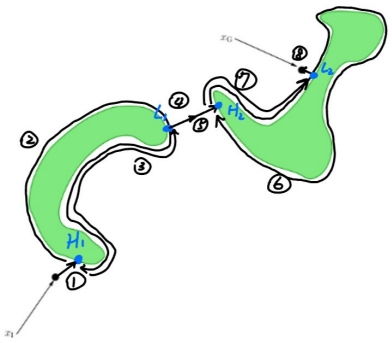



Figure 3: Navigation route from $x_I$ to $x_G$ using Bug1's algorithm.

### 1.1.2 Bug2 Algorithm

Bug 2 algorithm can be broken down into 4 steps:

1. Move toward the goal until reaching an obstacle.
2. Turn left and follow this obstacle until it returns to the line **connecting the start and goal positions**
3. If the robot can leave the obstacle toward the goal from this point **and** it is closer to the goal than the hit point, then leave toward the goal. Otherwise, continue around the obstacle.
4. Repeat to 1. until the robot reaches the goal.

Figure 4 shows the navigation when we hit the first obstacle. Here is a step-by-step breakdown:

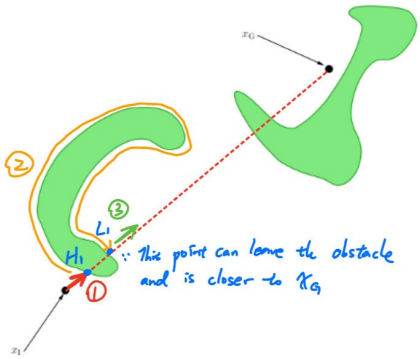



Figure 4: When the robot encounters the first obstacle. The number indicates the path sequence that the robot takes.

The robot first follows the shortest available path from $x_I$ to $H_G$ and reaches obstacle 1 at $H_1$. It turns left and travels around obstacle 1 until reaching $L_1$, which is on the line that connects the $H_1$ and the goal $x_G$. Since the robot can leave at $L_1$ and $L_1$ is also closer to $x_G$ than $H_1$, the robot can leave obstacle 1 at $L_1$.

The robot will next encounter obstacle 2, see Figure 5

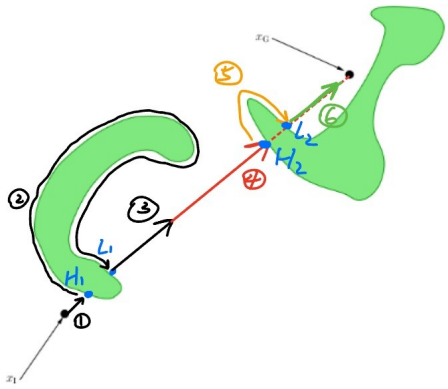



Figure 5: When the robot encounters the second obstacle.

Similar to the situation when the robot meets obstacle 1, it first travels the shortest available path to $H_G$ until reaching the obstacle at $H_2$. The robots then turn left and travel around the obstacle until reaching back to the line connecting $H_2$ and $x_G$, i.e. $L_2$ in the graph. Since the robot can leave at $L_2$ and $L_2$ is also closer to $x_G$ than $H_2$, the robot can leave obstacle 2 at $L_2$.

The robot's full route to travel from $x_I$ to $x_G$ using the Bug2 algorithm is shown in Figure 6.

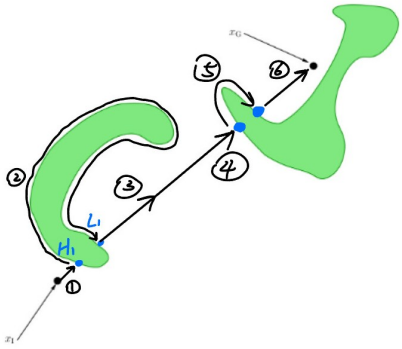



Figure 6: Navigation route from $x_I$ to $x_G$ using Bug2's algorithm.