Autonomous Systems

Lab #2 - Potential Functions

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Date of Submission:

06/11/2024

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1. Final Outcome:

The following sub-sections show the results for each exercise of the lab for different maps.

1.1. Grid-Map:

Figures 1 shows the grid-maps used for testing the different functions in this Lab. All the grid-maps are made by importing their respective images and then setting black cells (occupied) to a value of 1 and white cells (free) to a value of 0. Table 1 shows the start and goal points for each map that will be used in the next sections.

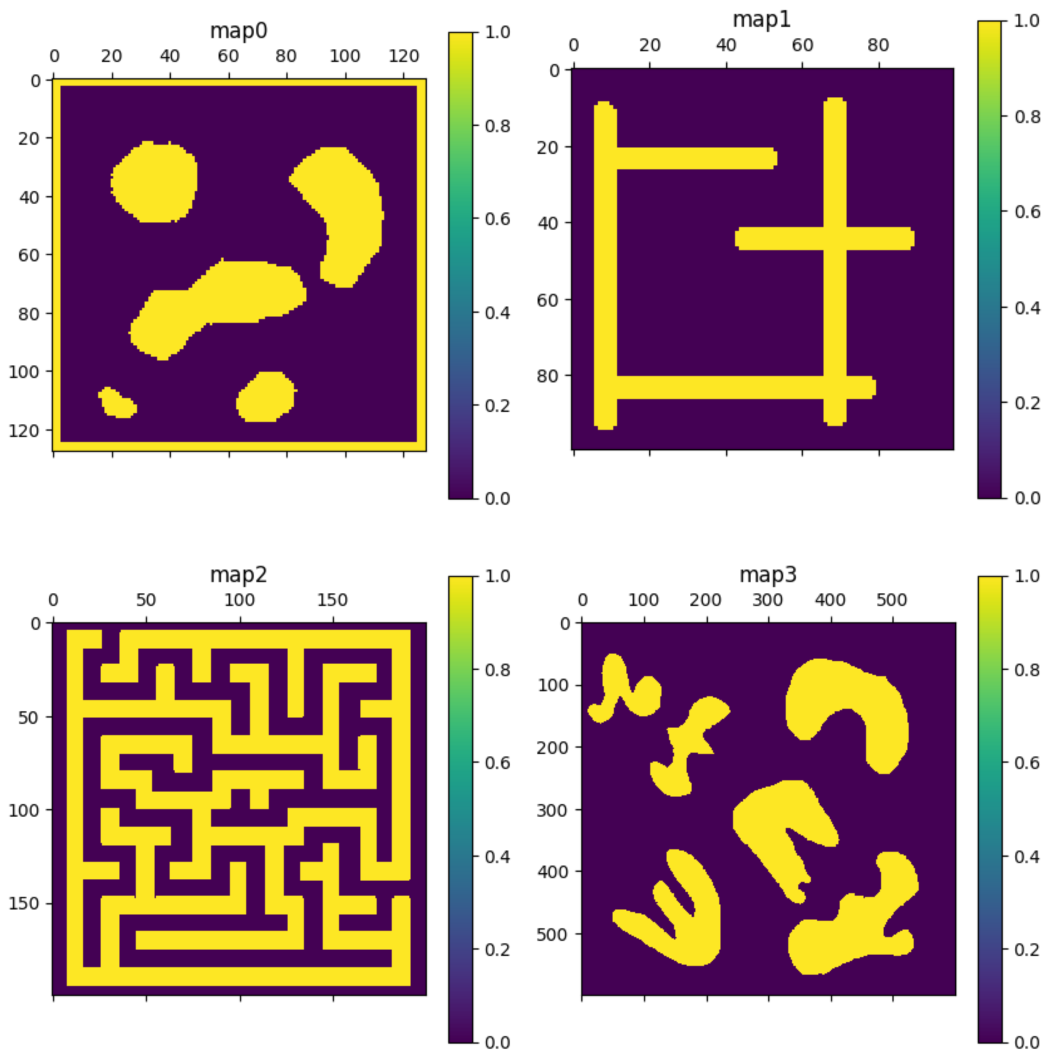

Fig.1: Grid-maps for different maps that were used to test our implementations

Map	Start	Goal
0	(10,10)	(110,40)
1	(60,60)	(90,60)
2	(8,31)	(139,38)
3	(50,90)	(375,375)

Table.1: Start and Goal points for each map

1.2. Attraction Potential:

Figure 2 shows the Attractive potential for each map, calculated using the quadratic potential energy from the goal point of each map provided in Table 1. The value of ζ was set equal to 0.001 in all maps.

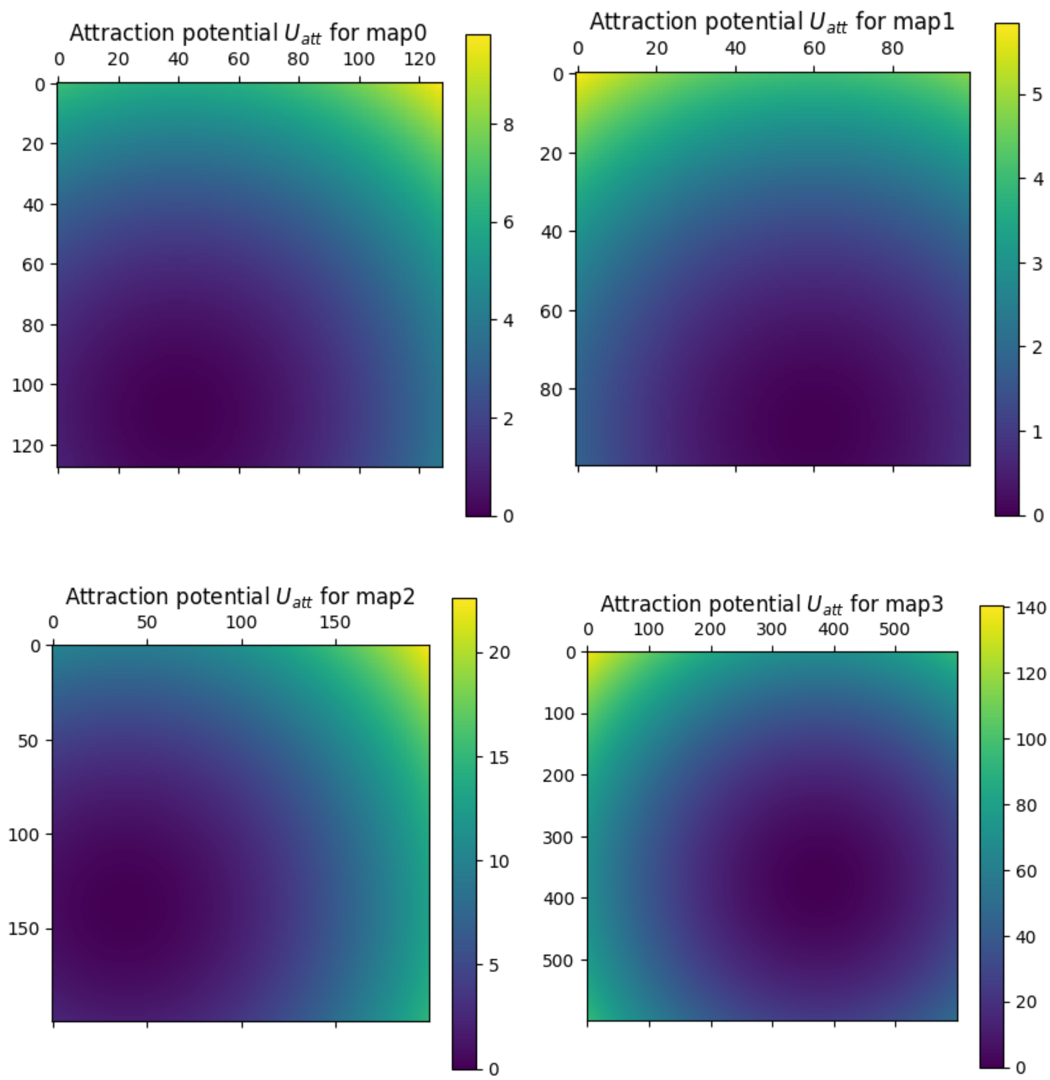

Fig.2: Attractive Potential for each map for goal points presented in Table.1

1.3. Distance Maps

Figure 3 shows the distance maps calculated using the **Brushfire** algorithm, to calculate the distance between a cell and its nearest obstacle.

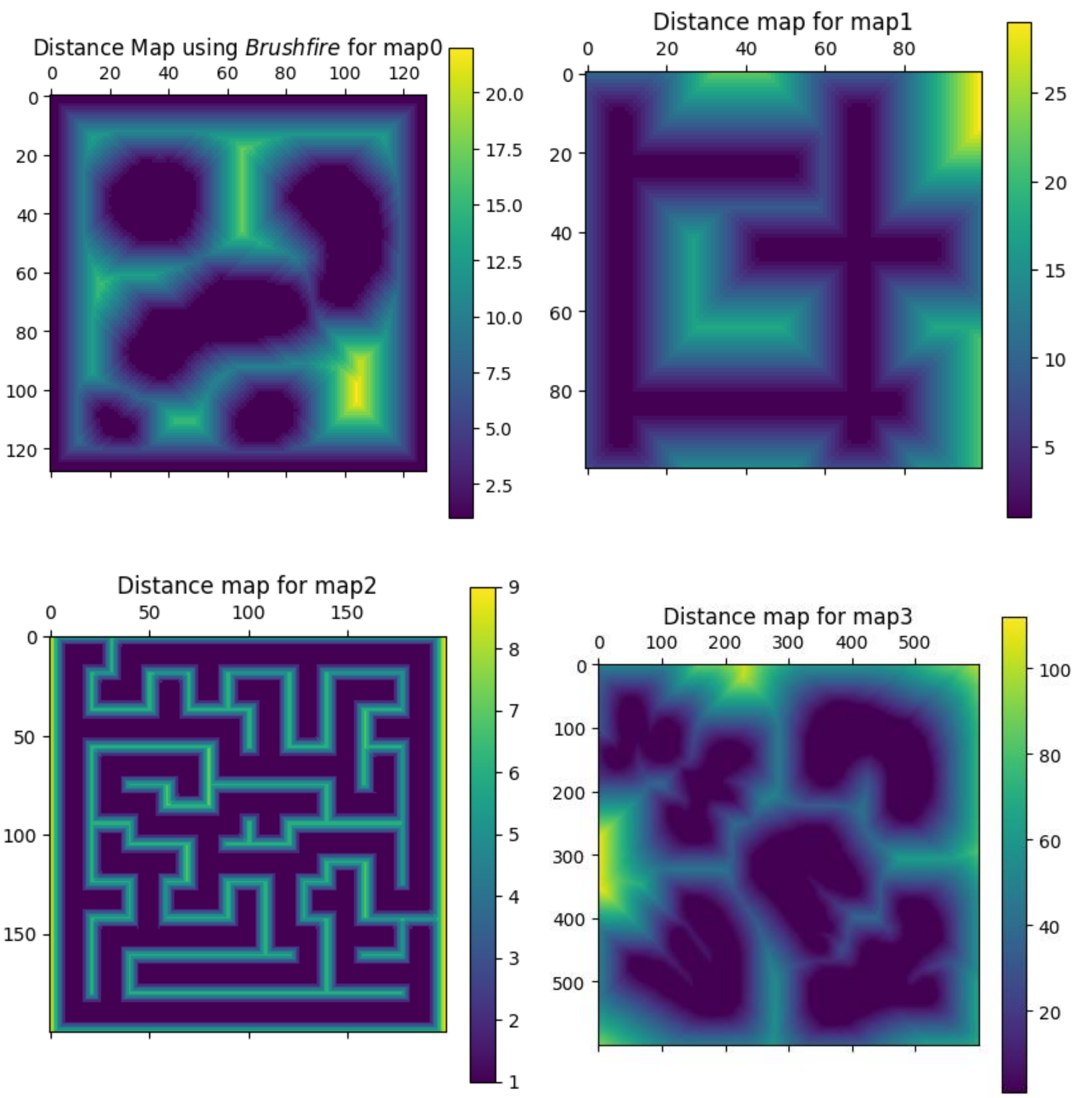

Fig.3: Distance Maps for each map calculated using Brushfire algorithm

1.4. Repulsive Potential

Figure 4 shows the repulsive potential field for all the maps calculated the distance maps from section 1.3. The value of η (repulsive force strength) is 5 and Q (threshold distance beyond which potential is zero) is 30.

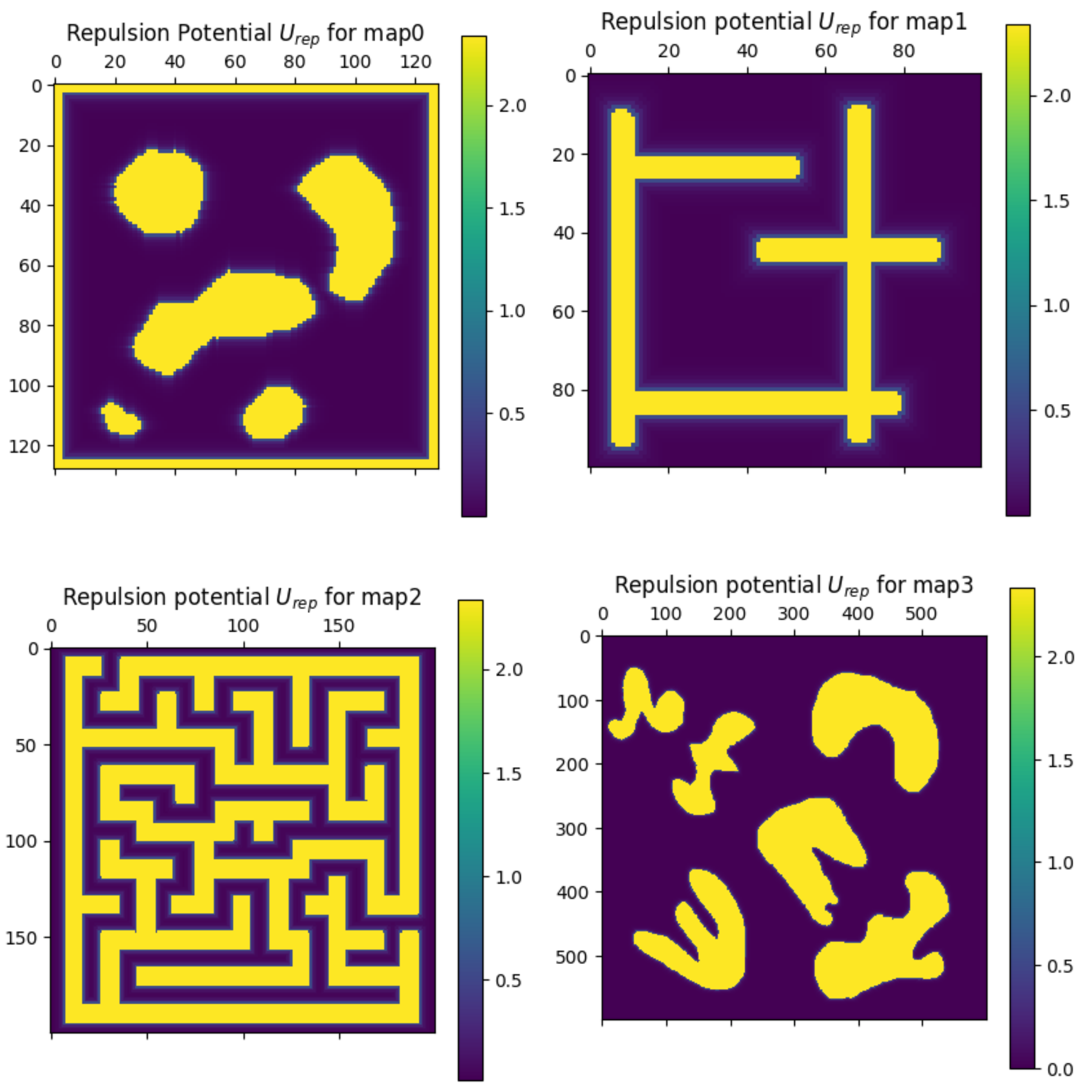

Fig.4: Repulsive Potential Field for every map calculated with $\eta = 5$ and $Q = 30$

1.5. Total Potential

The Total Potential Field of the Grid-map is calculated as the sum of the Attraction and Repulsion fields. Figure 5 shows the total potential fields for all the maps.

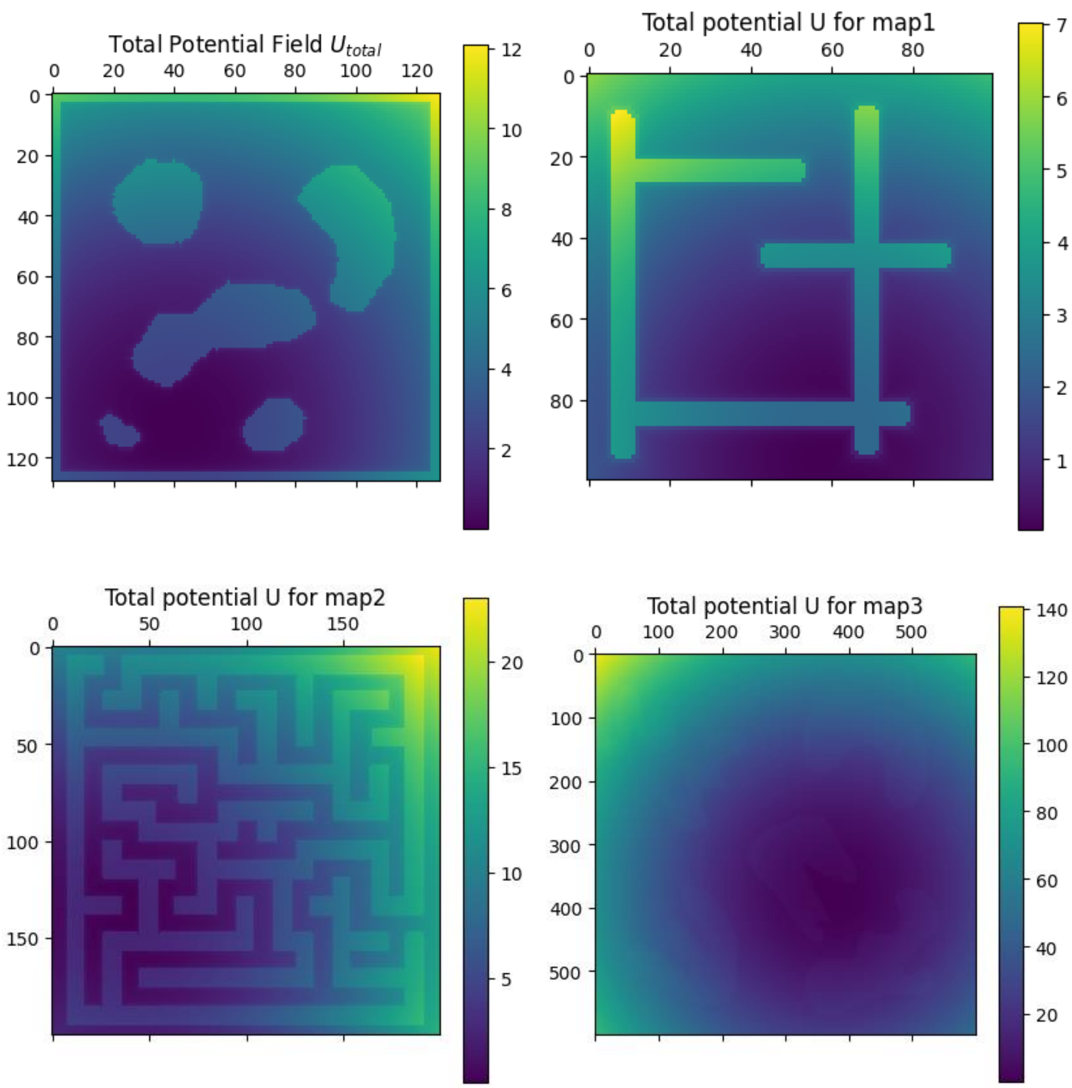

Fig.5: Total Potential Field for all maps

1.6. Gradient Descent

This section shows the results of applying the **Gradient Descent** algorithm to the total potential field from section 1.5. Gradient Descent was applied using both connectivity 4 and connectivity 8. Figure 6 shows the gradient descent using connectivity 4, while Figure 5 shows the algorithm with connectivity 8. Gradient descent gets stuck in local minimum in most cases, thus the need for a different planner.

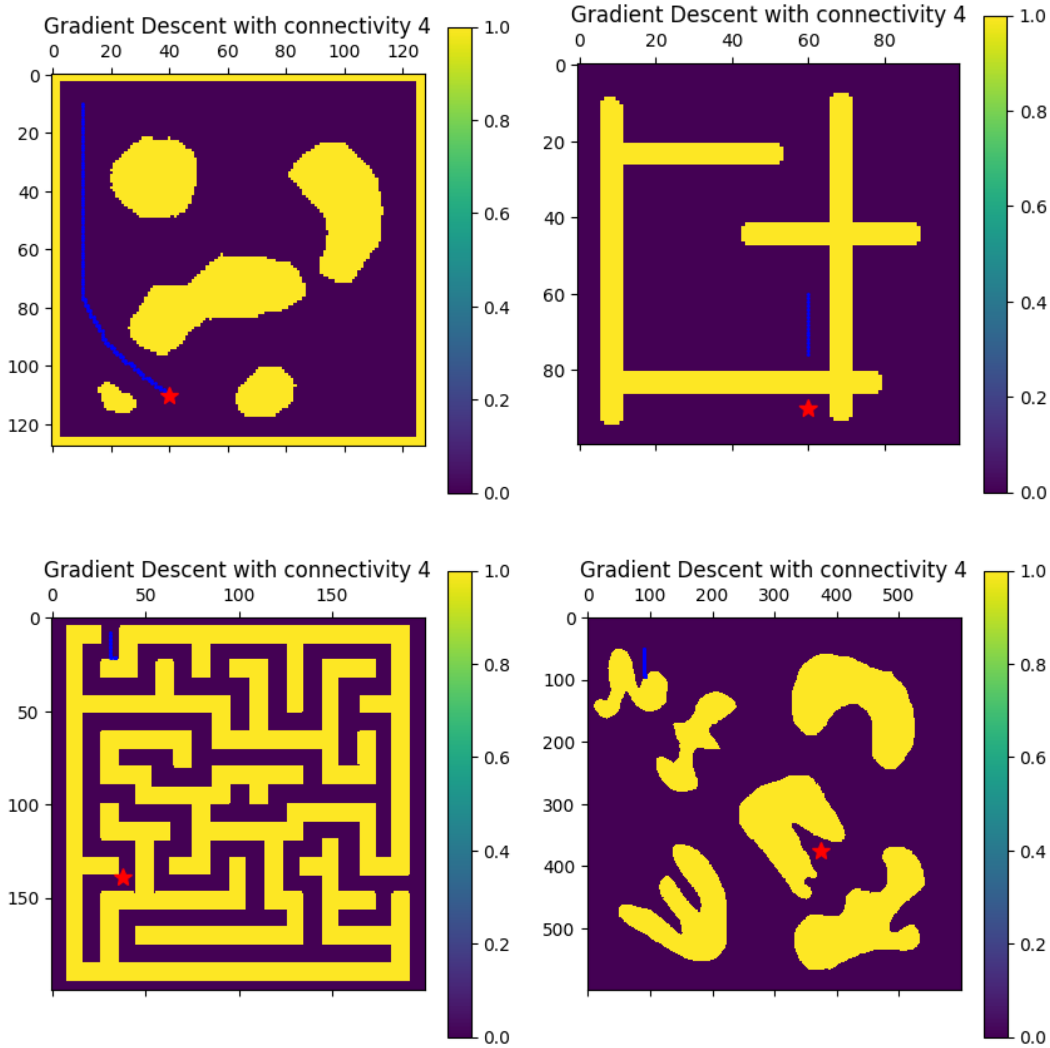

Fig.6: Gradient Descent applied with connectivity 4 to all maps.

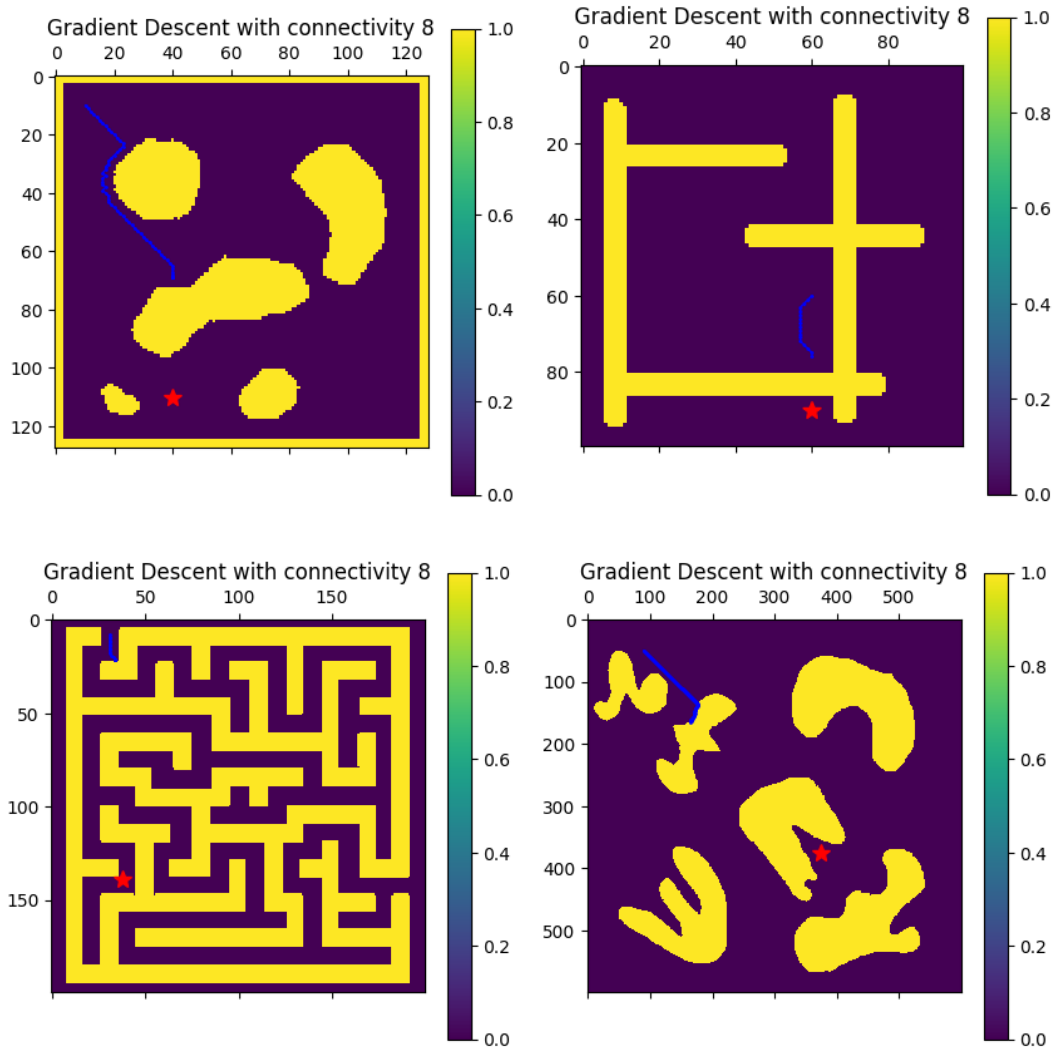

Fig.7: Gradient Descent applied with connectivity 8 to all maps.

1.7. Wave-Front Planner

This section shows the results for both the **Wave-Front Planner** and the Path generated using the resulting wave-map. The wave map was made using both connectivity 4 and 8, and those maps were used to find the path using both types of connectivity. Figures 8 and 9 show the wave-maps and the path generated using connectivity 4 respectively, while figures 10 and 11 show the wave-maps and paths generated using connectivity 8 respectively. The **Wave-Front Planner** can find a path in all maps and does not get stuck at local minimums.

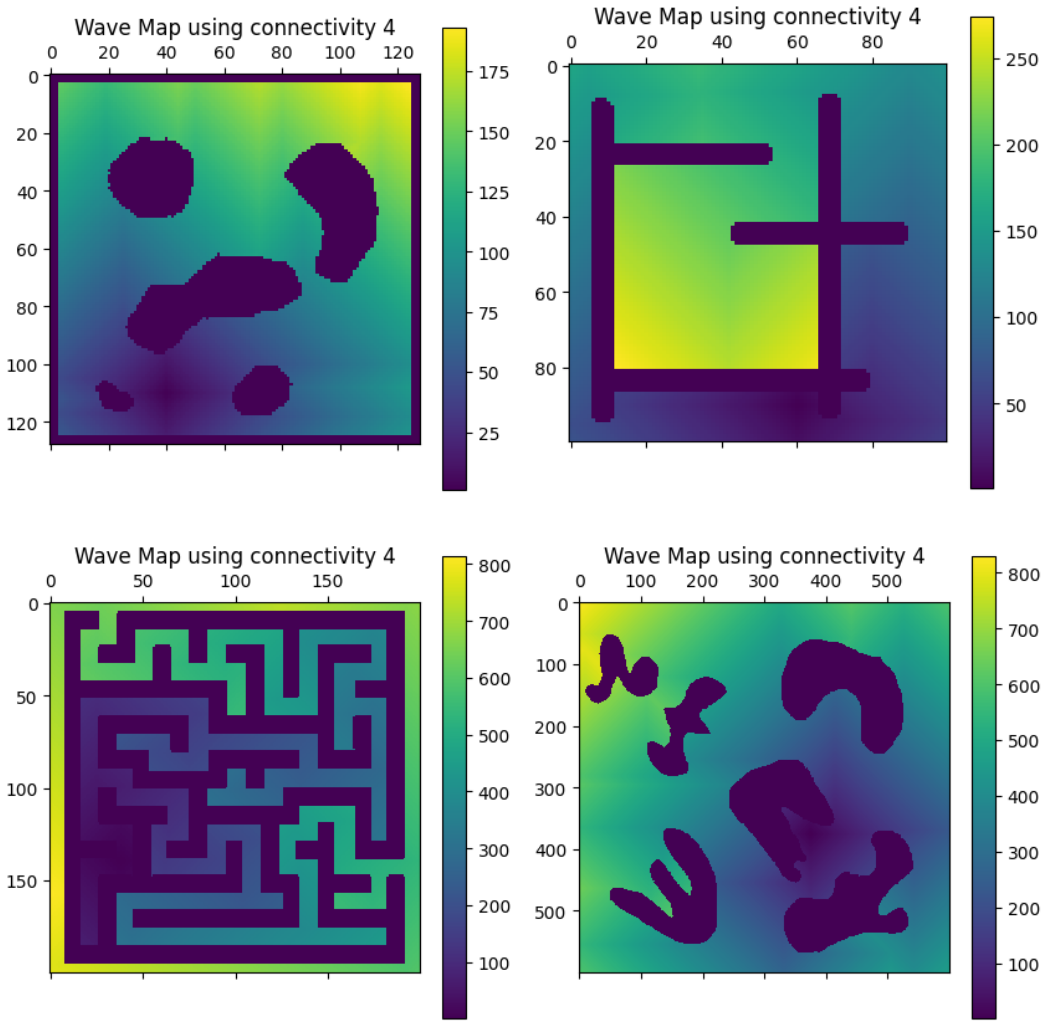

Fig.8: Wave-map using connectivity 4

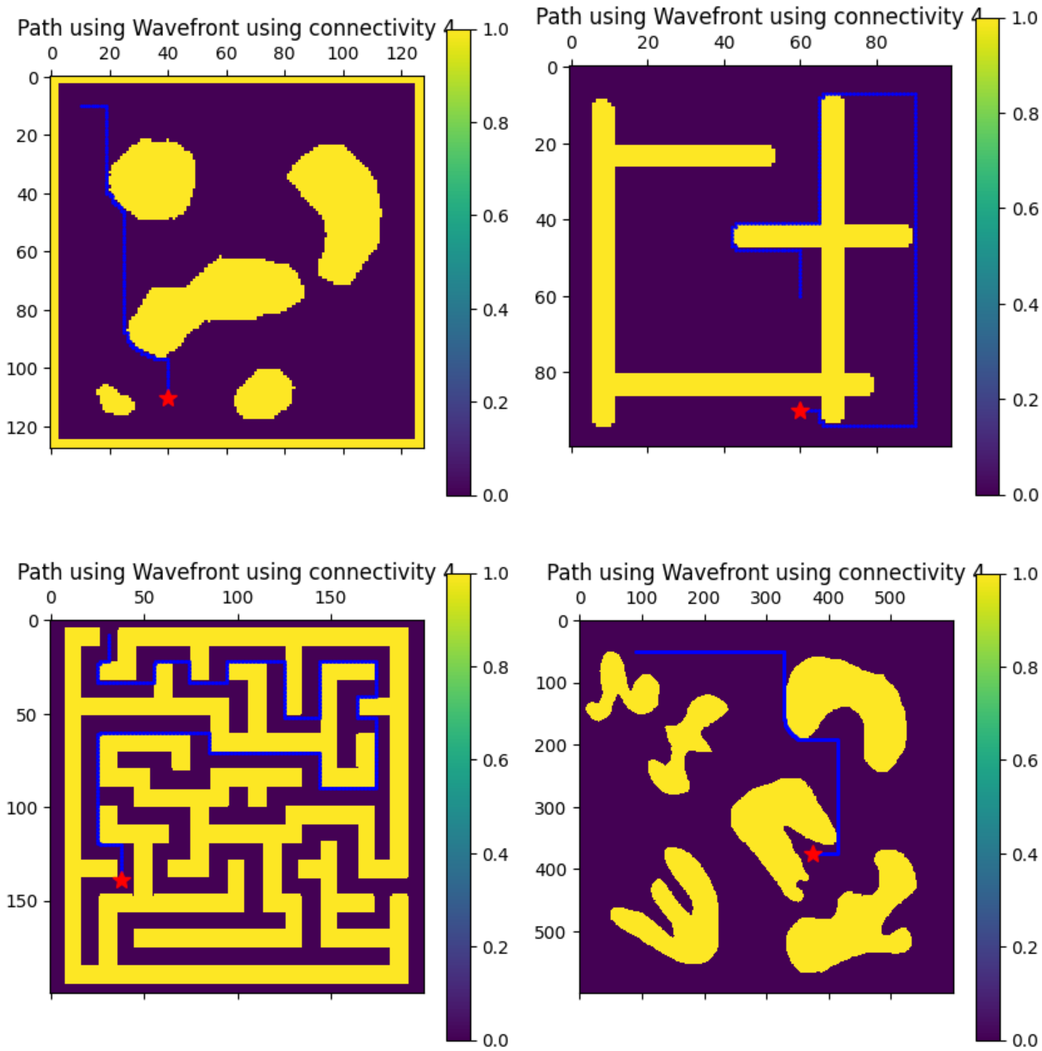

Fig.9: Path generated using Wave-Front Planner using connectivity 4

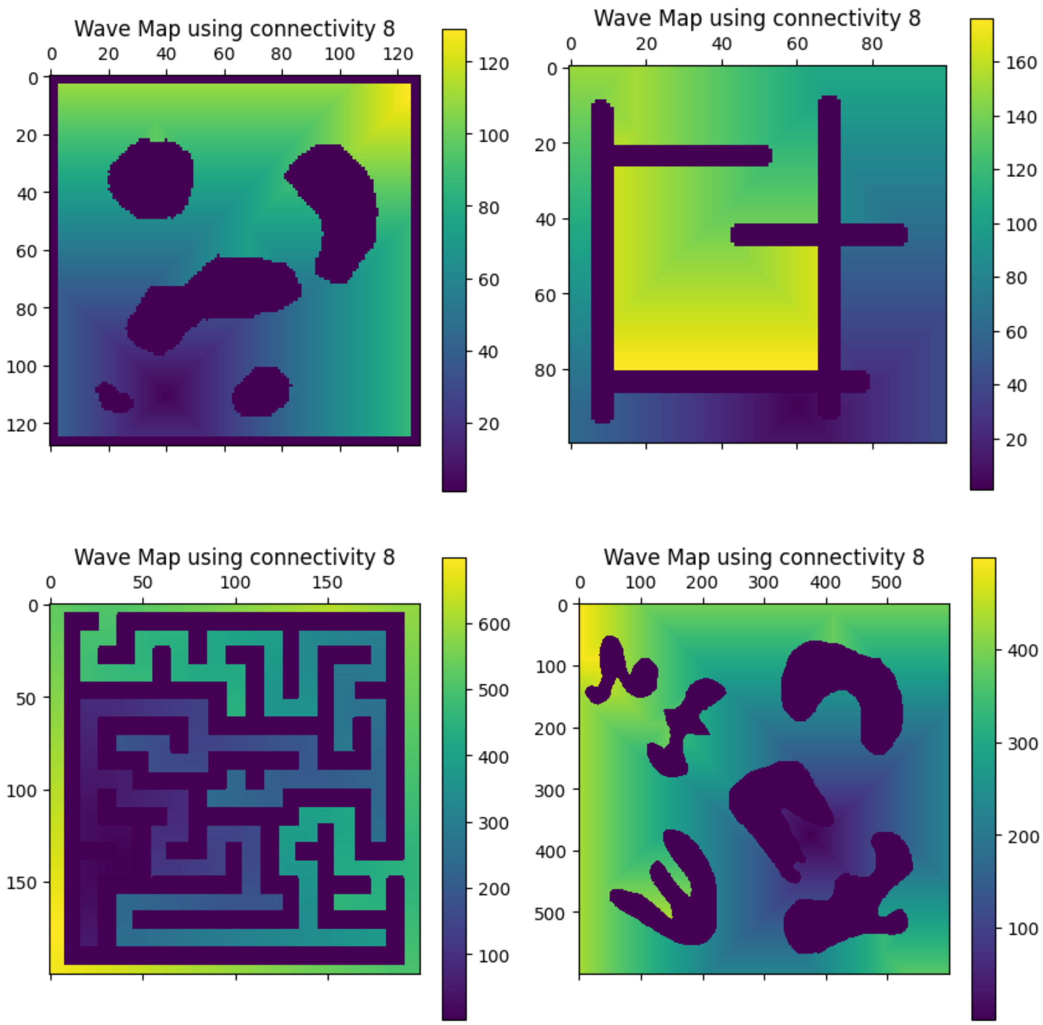

Fig.10: Wave-map using connectivity 8

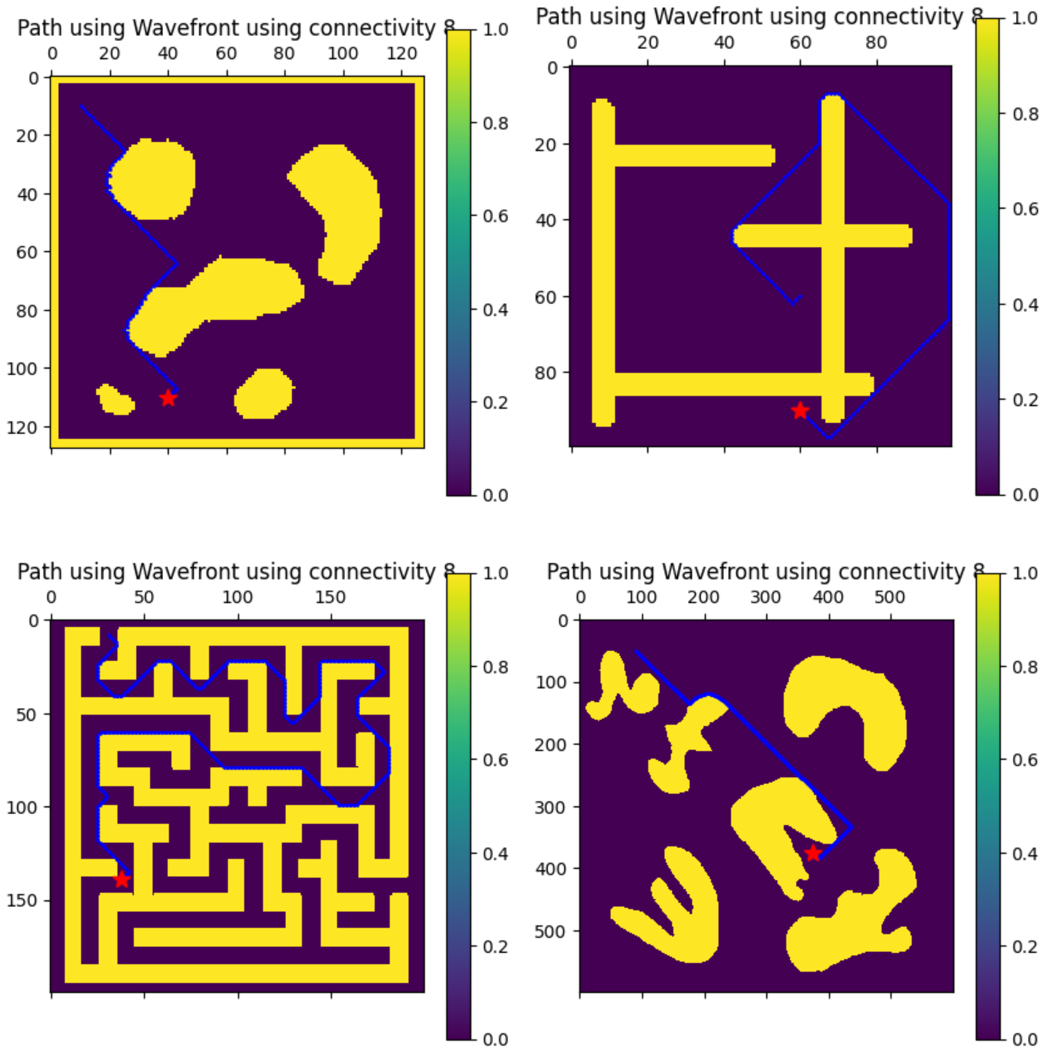

Fig.11: Path generated using Wave-Front Planner using connectivity 8

2. Implementations:

This section includes the implementation flow charts for all the algorithms used in this lab.

2.1. Attraction Potential Function:

Figure 12 shows the Flow diagram for the **Attraction Potential Function.**

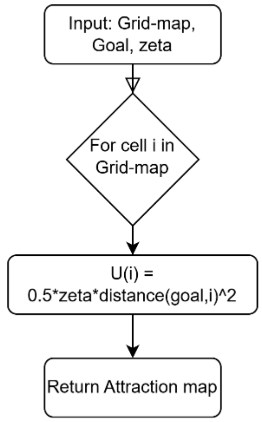

Fig.12: Flow Chart for Attraction Potential Function

2.2. Brushfire Algorithm:

Figure 13 shows the Flow chart for implementing the **Brushfire** algorithm.

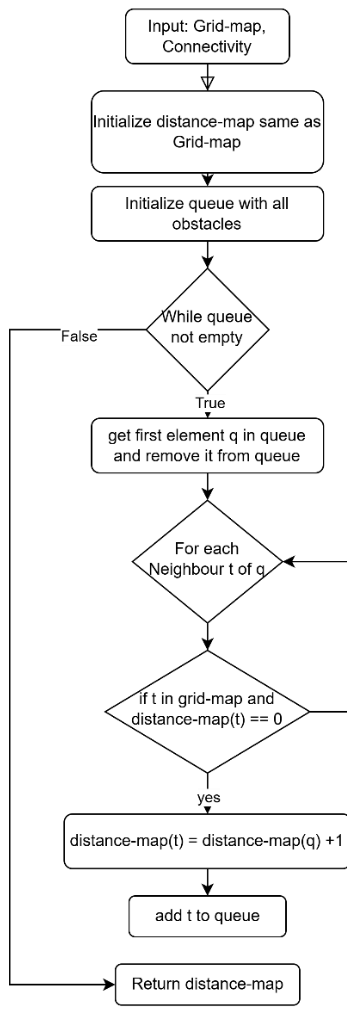

Fig.13: Flow Chart for Brushfire.

2.3. Repulsive Potential Function:

Figure 14 shows the flow chart for implementing the Repulsive Potential Function

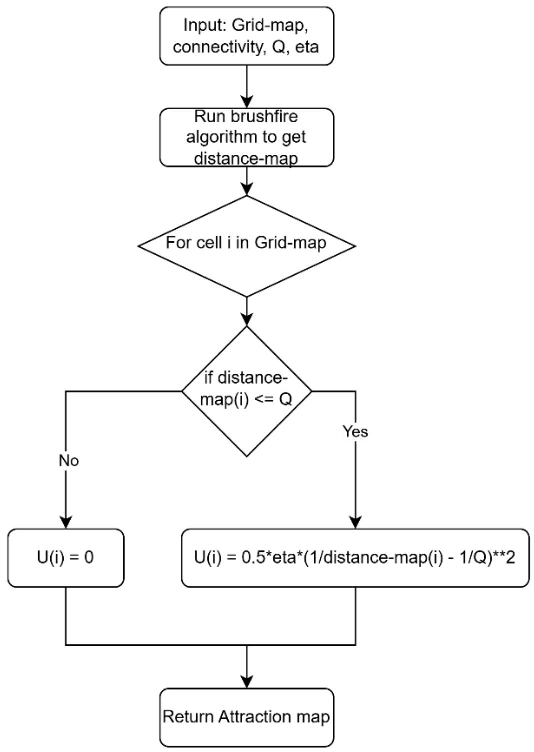

Fig.14: Flow Chart for Repulsive Potential Function

2.4. Total Potential Function:

The total Potential Function is the sum of the Attractive Potential Function and the Repulsive Potential Function.

2.5. Gradient Descent Algorithm:

To make sure that the algorithm does not get stuck in an infinite loop, we used a threshold of 500 for the number of iterations that can be done before returning the path. Figure 15 shows the flow diagram for the algorithm.

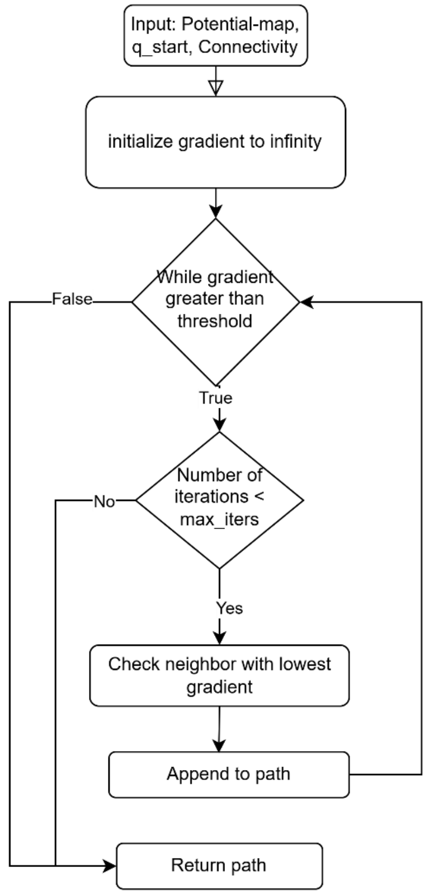

Fig.15: Flow Chart for Gradient Descent.

2.6. Wavefront Planner Algorithm:

We used a similar method to the **Brushfire** algorithm in section2.2, but the wave expands from the goal instead of the obstacles. The flow chart for **Wavefront Planner** is shown in figure 16.

2.7. Find Path:

Finally, using the generated wave-map from section 2.6, we apply a version gradient descent that follows the minimum of the neighbors until it reaches the goal. Figure 16 shows the flow chart for **Find Path**.

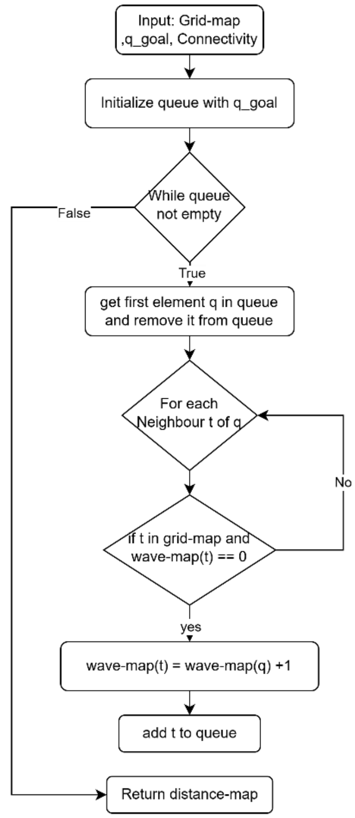

Fig.16: Flow Chart for Wavefront planner.

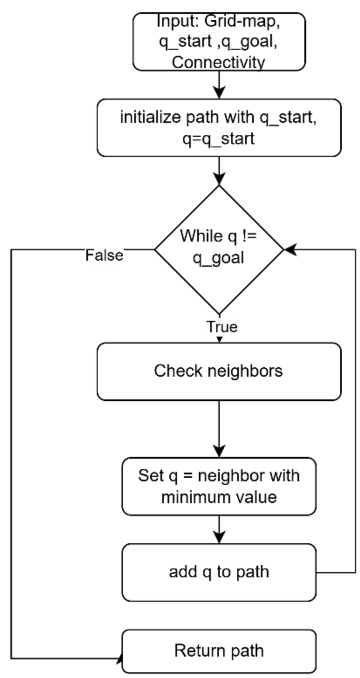

Fig.17: Flow Chart for Find Path function.

3. Challenges:

3.1. Testing Brushfire and Wavefront planner:

Because of the relatively large size of the grid-maps, testing the **Brushfire** algorithm while implementing was difficult, as there was no easy way to see where the fault was happening (due to the large number of iterations, visualizing the map at each iteration or debugging the code is almost impossible).

The solution to this was to make a small 10x10 grid-map as a testing environment. This allowed for easy visualization of the evolution of the distance-map, making debugging the algorithm easier and more rapid. The same map was used to test the **Wavefront-Planner**. The grid-map mentioned is shown below.

0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
0	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**
0	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
0	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**
0	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**
0	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
0	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
0	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

4. Conclusion:

In this lab we explored the use of potential functions as a method for path planning. We used the gradient descent algorithm to create a path from a start configuration to a goal configuration, however, the algorithm usually gets stuck at local minimum. Hence, it is recommended to use the Wave-front planner as it does not have a local minimum and can always find a path from start to goal configurations.

It is also recommended to normalize the attraction and repulsive potential functions in order to match their scales to prevent one of the maps being more dominant than the other in the total potential function, ensuring that the gradient descent can work across different environments.