Brief Overview

This path planning program uses an algorithm called Improved Q-Learning (IQL). A-Star uses a combination of heuristic value (h-value) along with distance traversed (g-value) to come up with a f-value that helps determine the path for a robot to take. IQL instead assigns each node a Q-value with the goal having the largest Q-value. Using the Q-values of each node as a guide, the robot is able to find a path from start to goal. IQL is an improvement over the Classical Q-Learning (CQL) algorithm. In CQL, all nodes are given an initial Q-value of 0. This means that the robot must randomly choose a node to go to until it finds the goal. However, this IQL attempts to get over this flaw by using an algorithm called flower pollination. This algorithm is used to mimic actual pollination in nature. Nodes/Flowers are chosen at random and pollen is distributed amongst them using local and global pollintaion equations for a set number of iterations. This way before the actual Q-learing starts, some nodes are already initialized with a Q-value meaning that the robot does not have to choose randomly between nodes to find the goal.

Important Points Regarding the Program

The original algorithm assumed the robot could only go in the four cardinal directions, however, in this program the robot can move diagonally at a 45 degree angle as well. The enivroment takes a while to create the larger the enviornment is. For the 300x300 enviornment, it may take up to a minute for the enivornment to be created. The larger the enviroment, the harder it is to make out the individual nodes, ensure that you view the graph at maximum size so that you may better see the nodes. It is possible for a path not to be found especially if there are more obstacles or if the starting and/or goal index are situated in the corner of the enviornment.

Hypothesis

My hypothesis regarding the results is that the algorithm would take longer the larger the enviornment was as well as take longer if the start and goal points were further apart.

Results

Given below are the results of various program runs. The time taken includes the time taken to run the algorithm as well as the time taken to plot the path.

100x100 Environment
Obstacle Percentage: 10%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	6
42,50	72,90	50	12
17,77	80,28	80	16
36,90	99,0	110	18
0,0	99,99	140	20

100x100 Environment
Obstacle Percentage: 20%

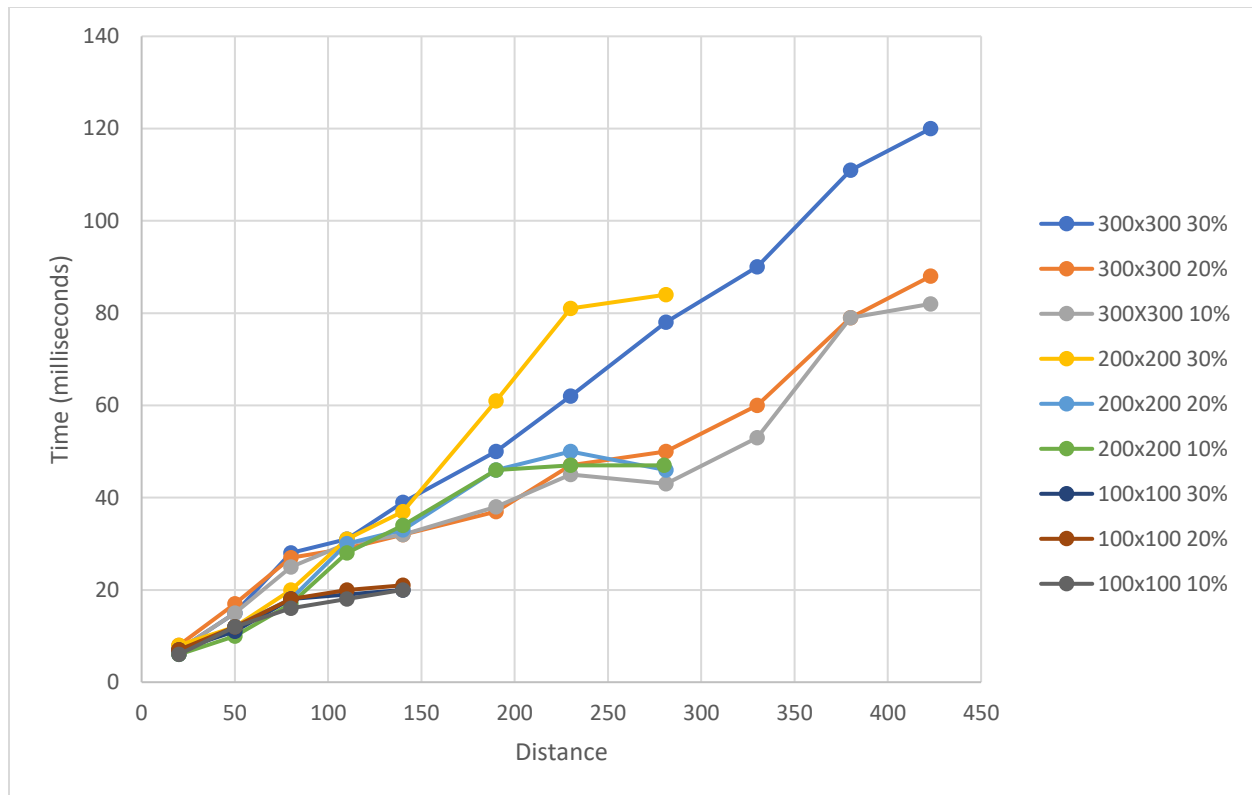| Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	7
42,50	72,90	50	12
17,77	80,28	80	18
36,90	99,0	110	20
0,0	99,99	140	21

100x100 Environment
Obstacle Percentage: 30%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	7
42,50	72,90	50	11
17,77	80,28	80	18
36,90	99,0	110	19
0,0	99,99	140	20

200x200 Environment
Obstacle Percentage: 10%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	6
42,50	72,90	50	10
17,77	80,28	80	17
36,90	99,0	110	28
0,0	99,99	140	34
150,170	20,31	190	46
47,190	190,10	230	47
0,0	199,199	280	47

200x200 Environment
Obstacle Percentage: 20%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	6
42,50	72,90	50	12
17,77	80,28	80	18
36,90	99,0	110	30
0,0	99,99	140	33
150,170	20,31	190	46
47,190	190,10	230	50
0,0	199,199	281	46

200x200 Environment
Obstacle Percentage: 30%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	8
42,50	72,90	50	12
17,77	80,28	80	20
36,90	99,0	110	31
0,0	99,99	140	37
150,170	20,31	190	61
47,190	190,10	230	81
0,0	199,199	281	84

300x300 Environment
Obstacle Percentage: 10%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	7
42,50	72,90	50	15
17,77	80,28	80	25
36,90	99,0	110	30
0,0	99,99	140	32
150,170	20,31	190	38
47,190	190,10	230	45
0,0	199,199	281	43
7,250	244,20	330	53
275,275	8,5	380	79
0,0	299,299	423	82

300x300 Environment
Obstacle Percentage: 20%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	8
42,50	72,90	50	17
17,77	80,28	80	27
36,90	99,0	110	29
0,0	99,99	140	32
150,170	20,31	190	37
47,190	190,10	230	47
0,0	199,199	281	50
7,250	244,20	330	60
275,275	8,5	380	79
0,0	299,299	423	88

300x300 Environment
Obstacle Percentage: 30%

Start Index	Goal Index	Approximate Distance Between Start and Goal	Time Taken (milliseconds)
5,5	20,18	20	7
42,50	72,90	50	15
17,77	80,28	80	28
36,90	99,0	110	31
0,0	99,99	140	39
150,170	20,31	190	50
47,190	190,10	230	62
0,0	199,199	281	78
7,250	244,20	330	90
275,275	8,5	380	111
0,0	299,299	423	120

Chart showing Time (milliseconds) versus Distance with the following series:
- 300x300 30%
- 300x300 20%
- 300X300 10%
- 200x200 30%
- 200x200 20%
- 200x200 10%
- 100x100 30%
- 100x100 20%
- 100x100 10%

Interpretation of Results

The results for the most part shows that the time taken increases the greater the path distance. The results also seem to show that the obstacle percentage begins to have more of an impact on time taken the greather the path distance is.

Screenshots

Here are some of the indices that were tested along with their respective graphs. The blue node represents the starting point and the green node represents the goal. The red color color is used to represent the nodes and path taken by the robot to go from start to finish.

```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
1

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
1

Enter starting index e.g.: 0,0. Range is from (0,0) to (99,99).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (99,99).
99,99

Creating Environment...

Path Found

Time Taken: 20.0 milliseconds
```
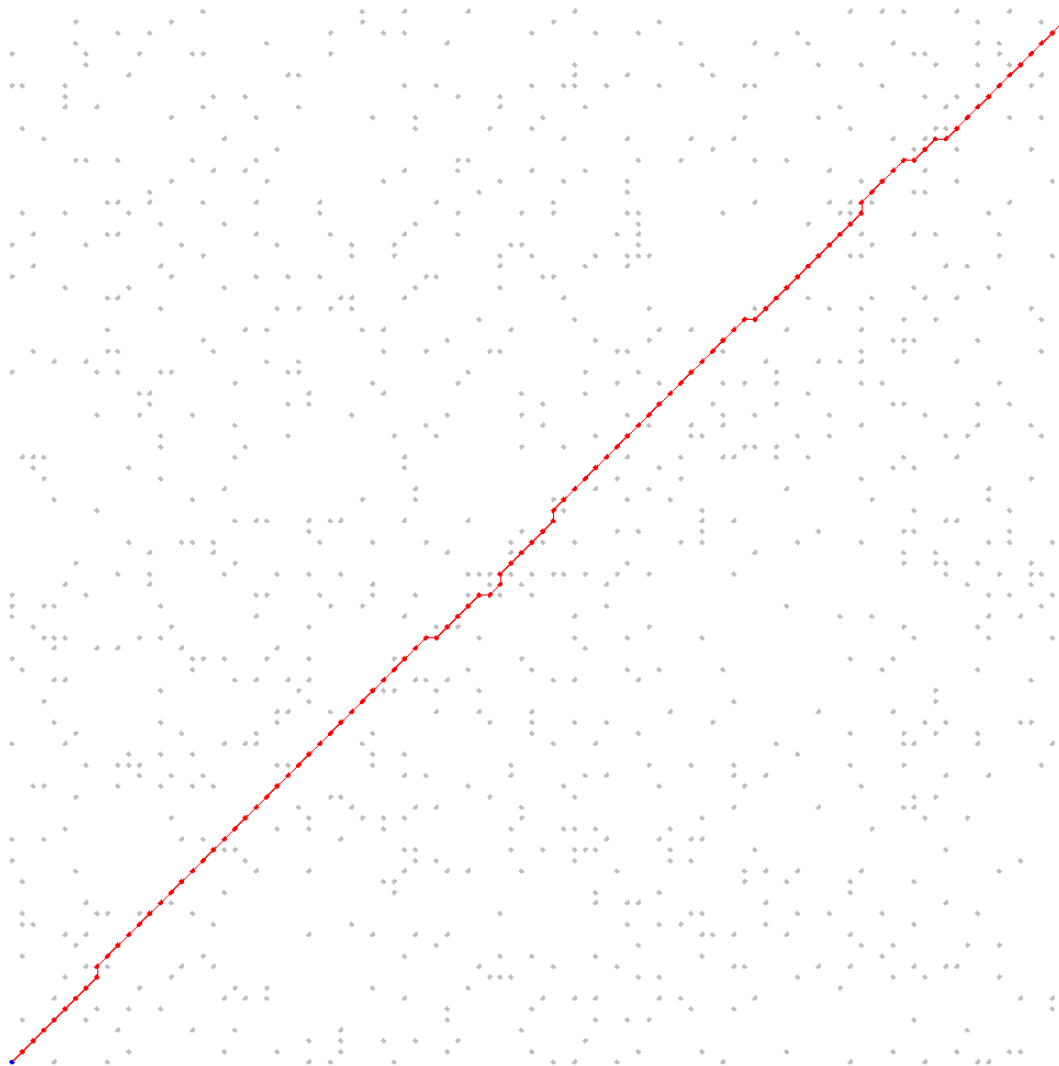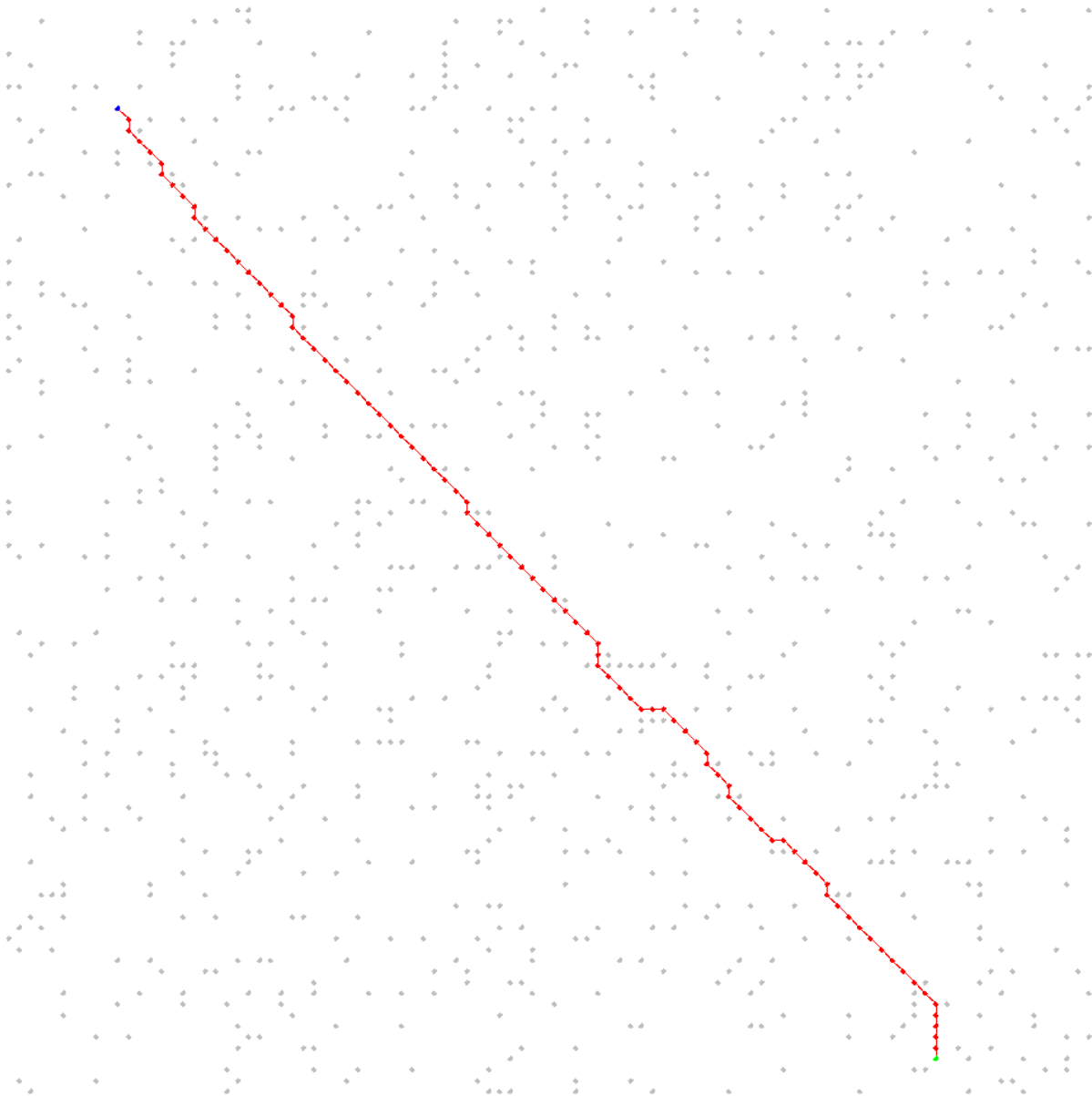
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
1

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
2

Enter starting index e.g.: 0,0. Range is from (0,0) to (99,99).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (99,99).
99,99

Creating Environment...

Path Found

Time Taken: 21.0 milliseconds
```

Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
1

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
3

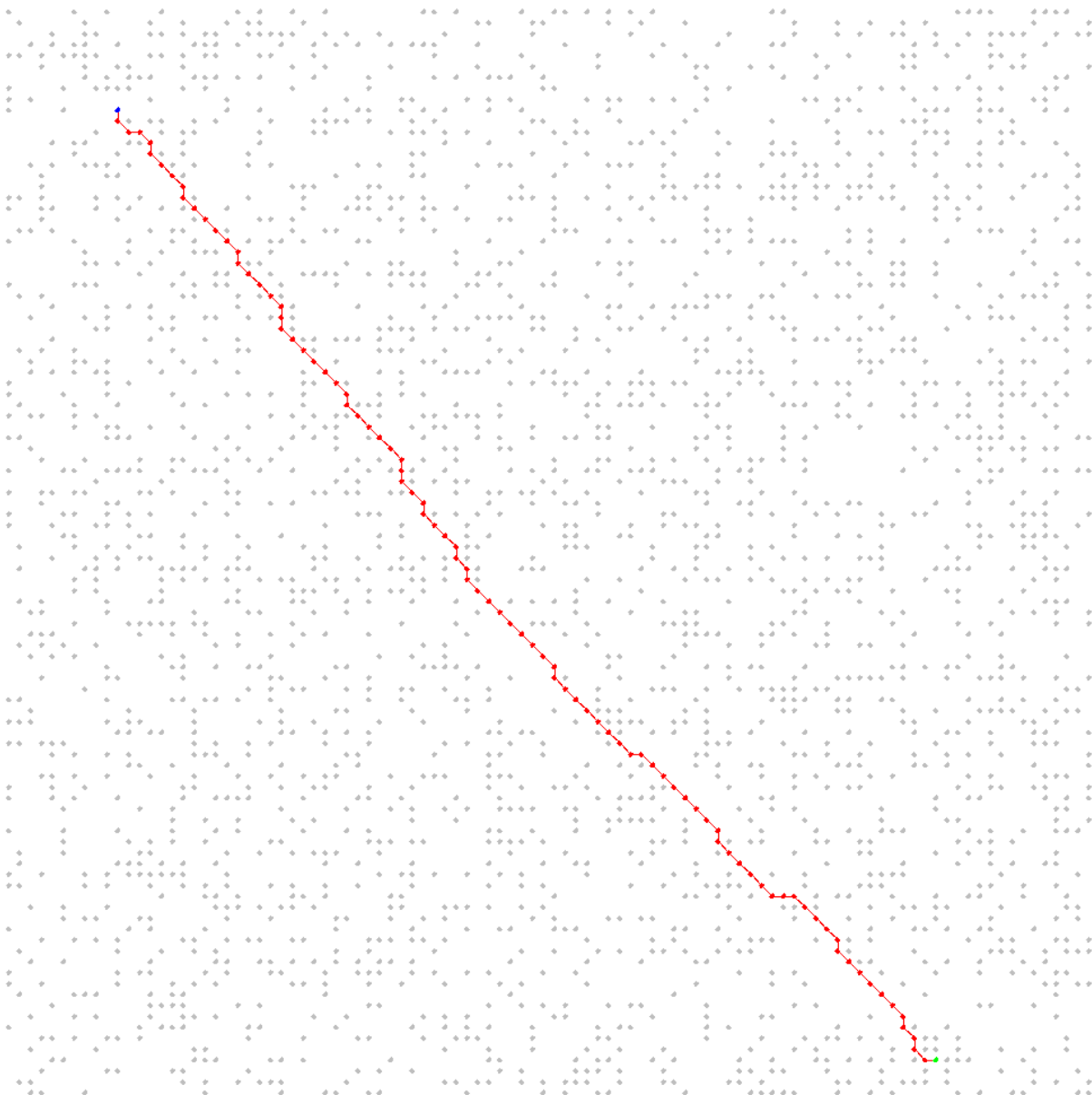Enter starting index e.g.: 0,0. Range is from (0,0) to (99,99).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (99,99).
99,99

Creating Environment...

Path Found

Time Taken: 20.0 milliseconds
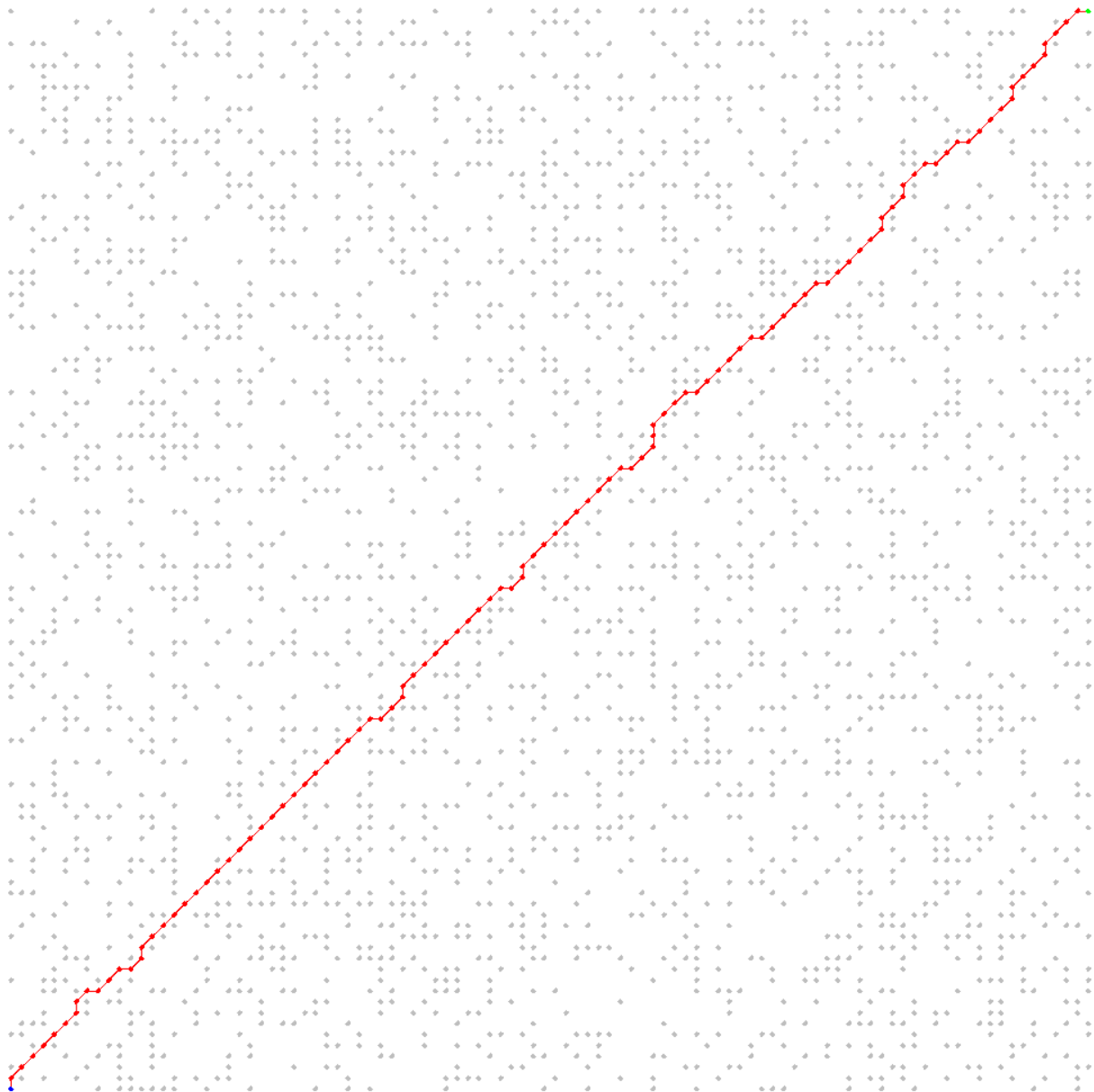
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
1

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
1

Enter starting index e.g.: 0,0. Range is from (0,0) to (99,99).
10,90
Enter goal index e.g.: 0,0. Range is from (0,0) to (99,99).
85,3

Creating Environment...

Path Found

Time Taken: 18.0 milliseconds
```

```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
1

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
2

Enter starting index e.g.: 0,0. Range is from (0,0) to (99,99).
10,90
Enter goal index e.g.: 0,0. Range is from (0,0) to (99,99).
85,3

Creating Environment...

Path Found

Time Taken: 19.0 milliseconds
```
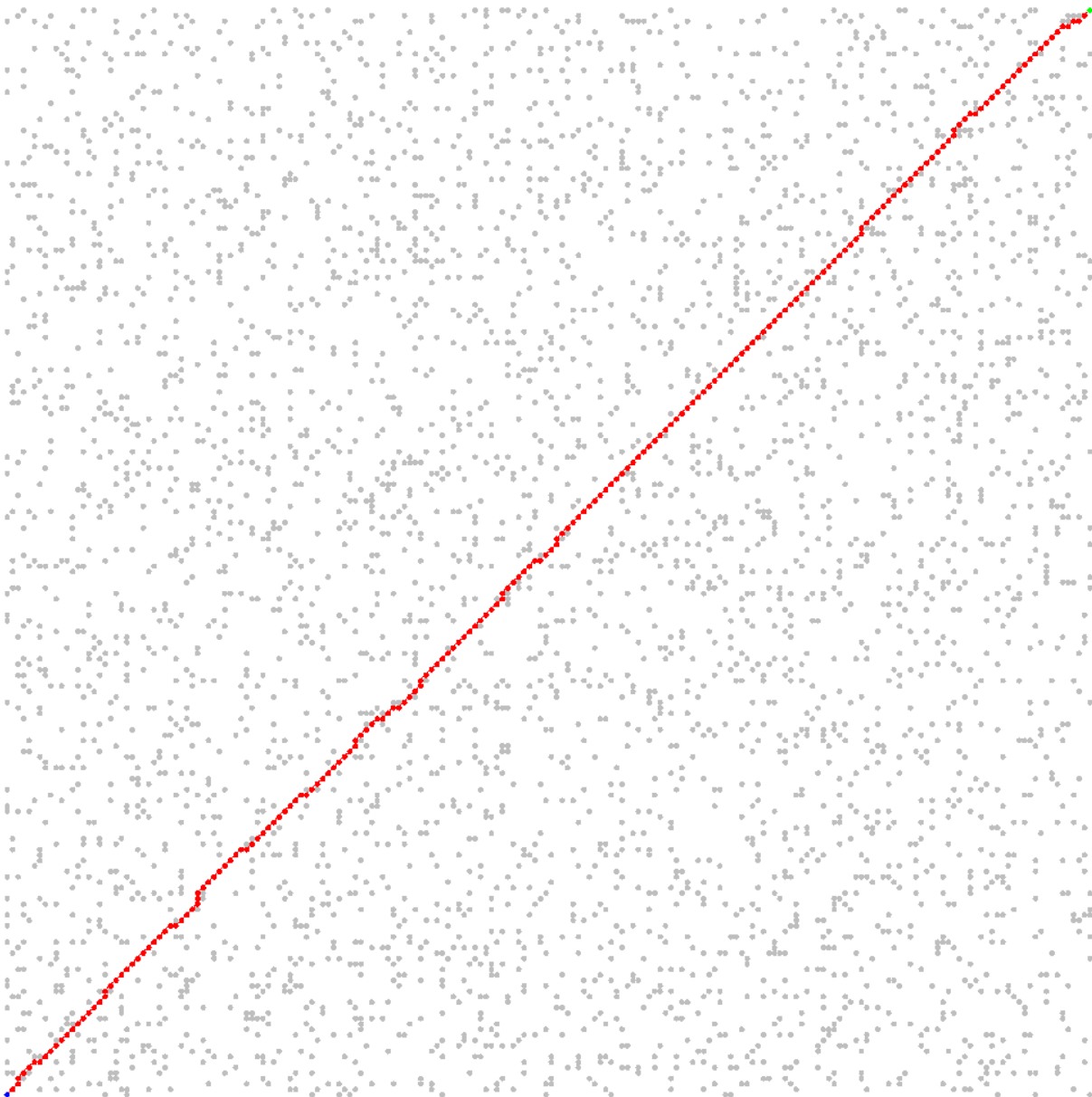
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
1

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
3

Enter starting index e.g.: 0,0. Range is from (0,0) to (99,99).
10,90
Enter goal index e.g.: 0,0. Range is from (0,0) to (99,99).
85,3

Creating Environment...

Path Found

Time Taken: 19.0 milliseconds
```
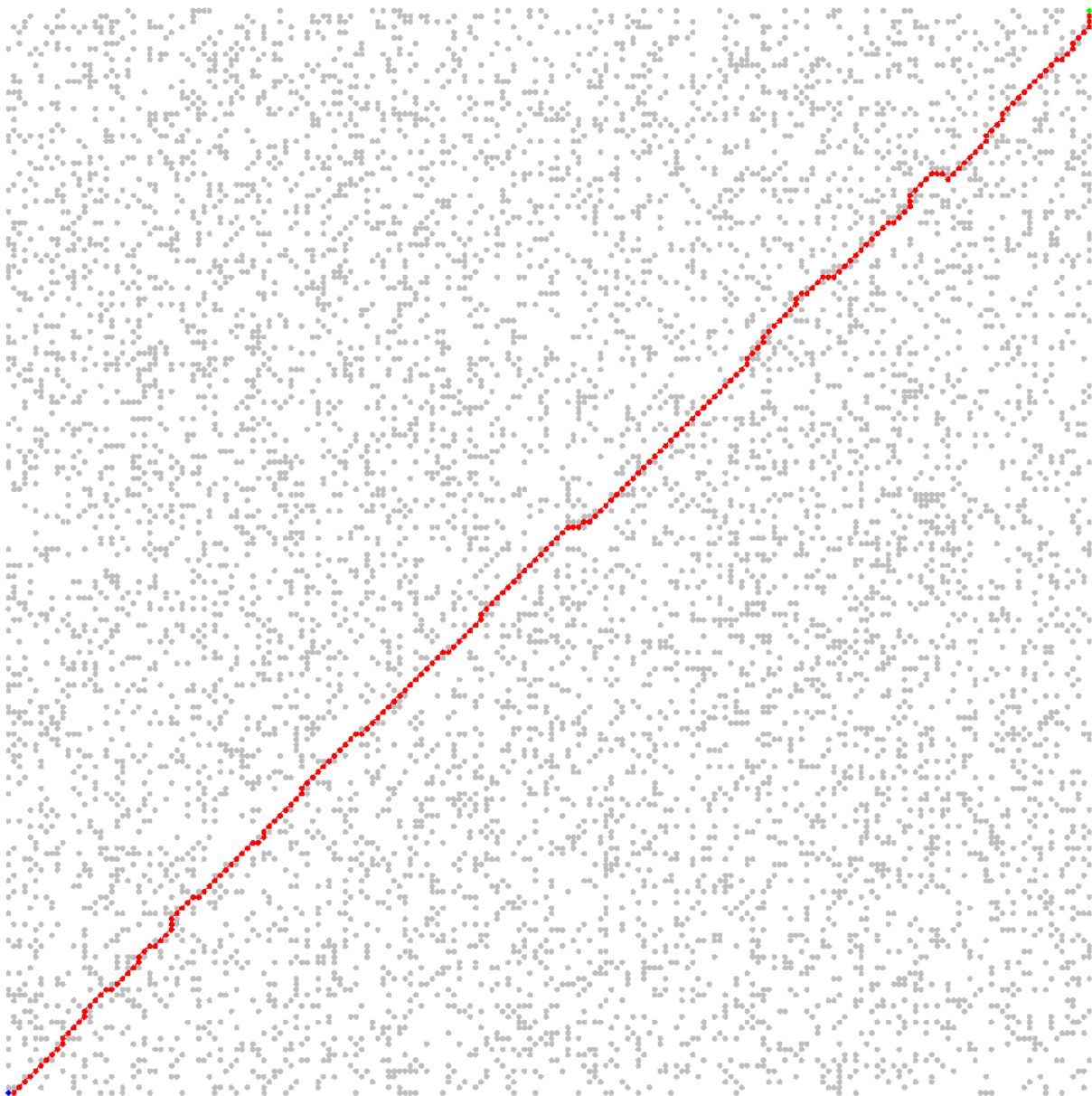
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
2

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
1

Enter starting index e.g.: 0,0. Range is from (0,0) to (199,199).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (199,199).
199,199

Creating Environment...

Path Found

Time Taken: 47.0 milliseconds
```
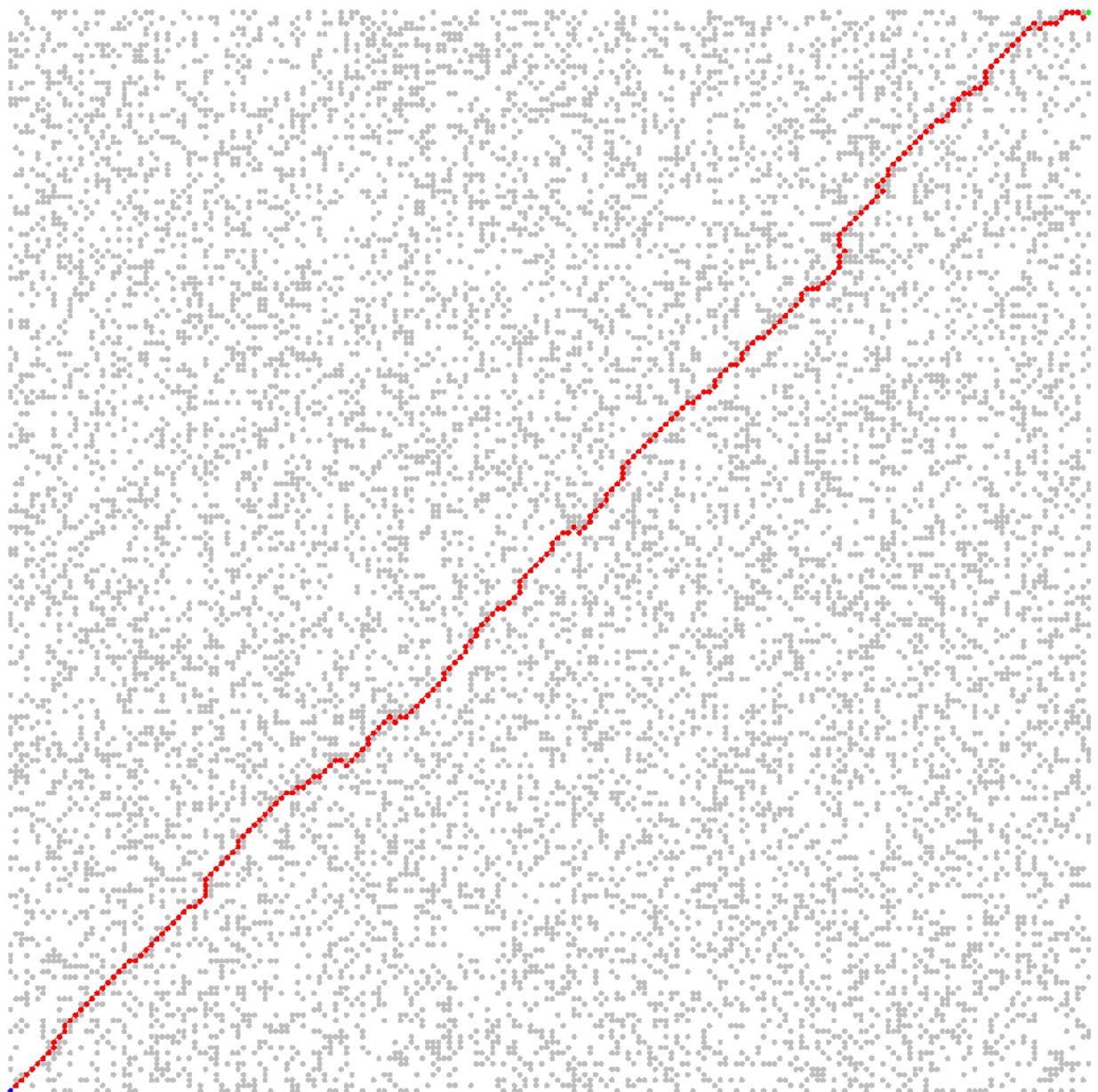
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
2

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
2

Enter starting index e.g.: 0,0. Range is from (0,0) to (199,199).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (199,199).
199,199

Creating Environment...

Path Found

Time Taken: 46.0 milliseconds
```
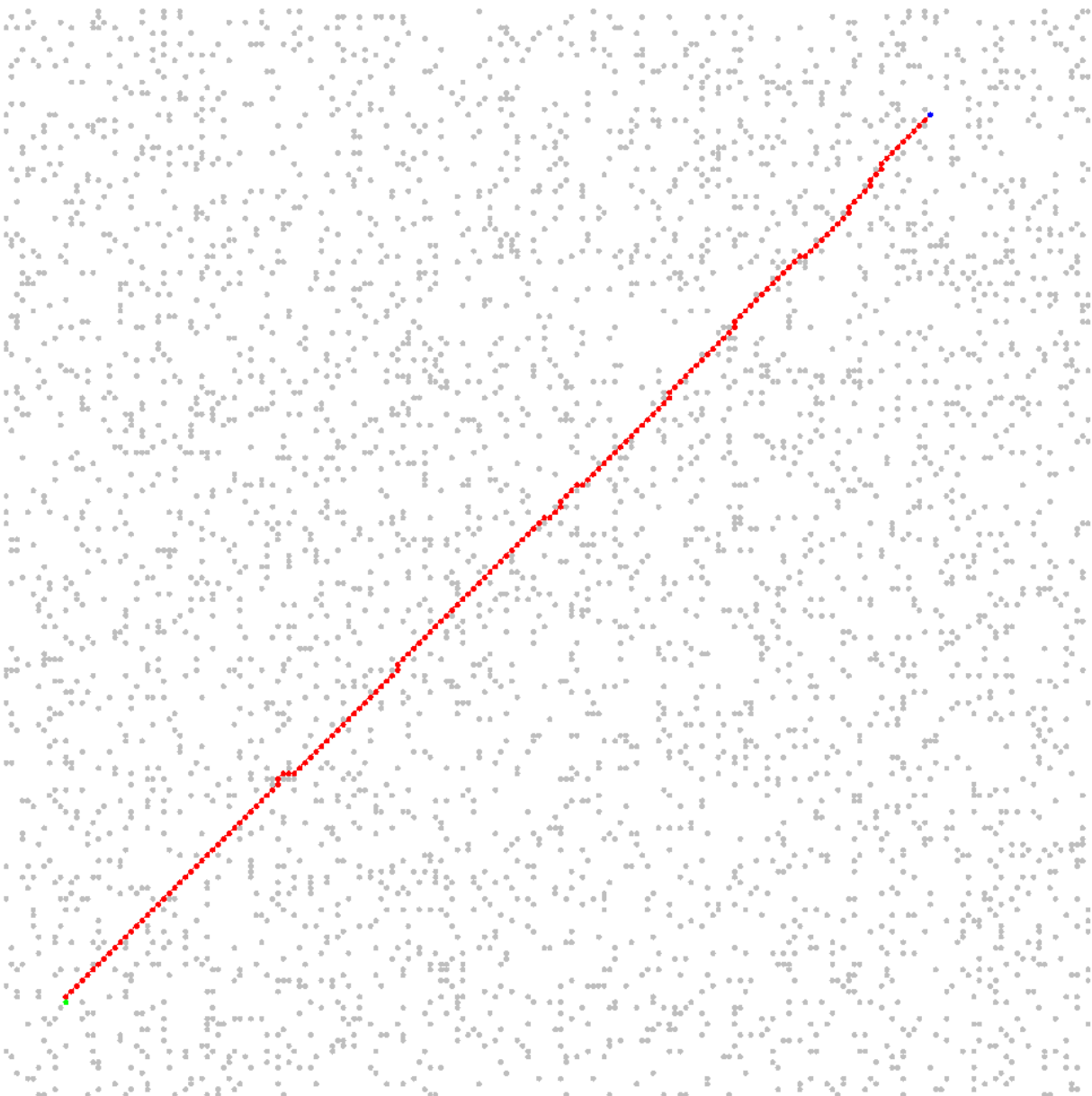
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
2

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
3

Enter starting index e.g.: 0,0. Range is from (0,0) to (199,199).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (199,199).
199,199

Creating Environment...

Path Found

Time Taken: 84.0 milliseconds

```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
2

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
1

Enter starting index e.g.: 0,0. Range is from (0,0) to (199,199).
170,180
Enter goal index e.g.: 0,0. Range is from (0,0) to (199,199).
11,17

Creating Environment...

Path Found

Time Taken: 47.0 milliseconds
```
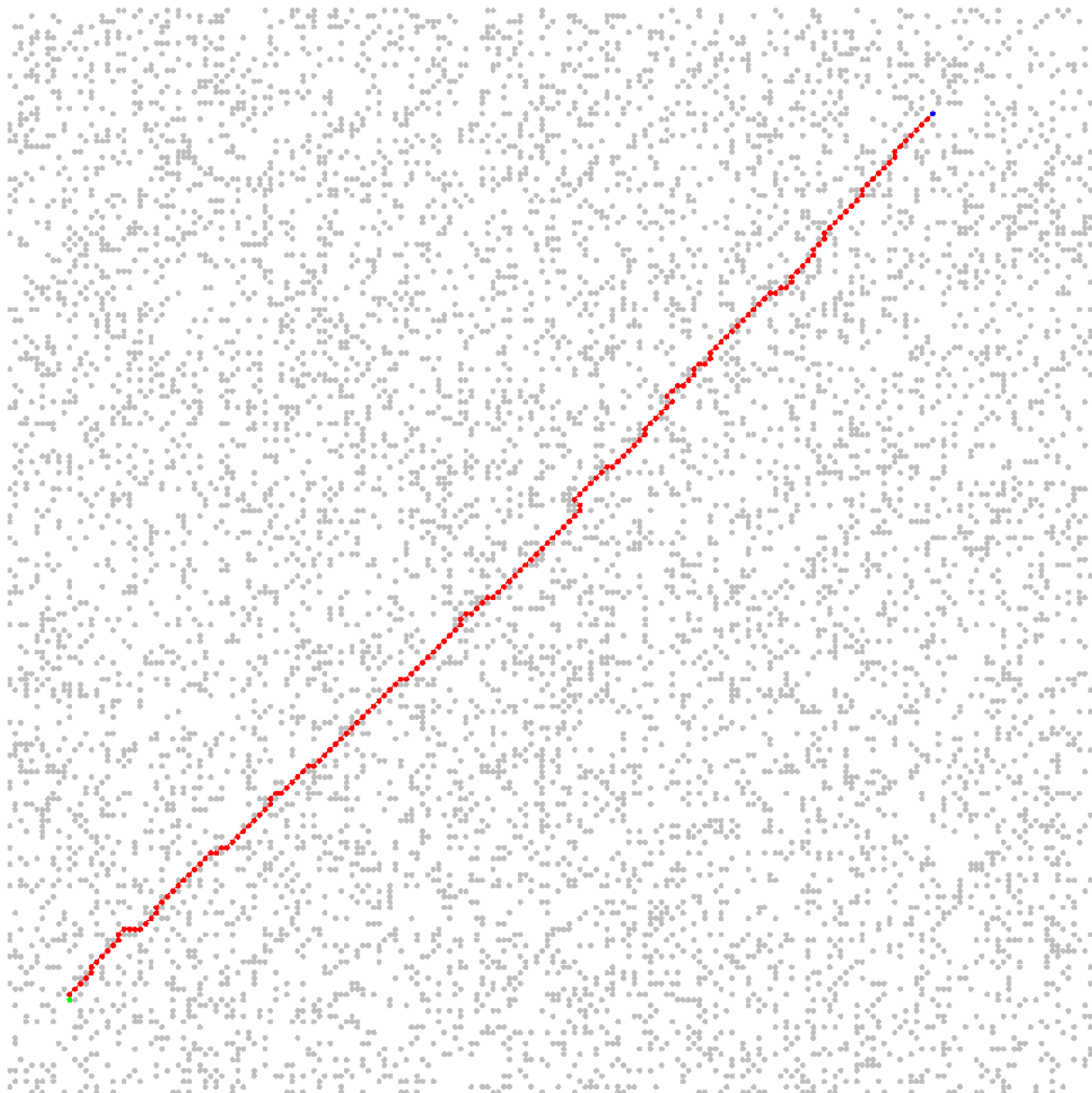
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
2

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
2

Enter starting index e.g.: 0,0. Range is from (0,0) to (199,199).
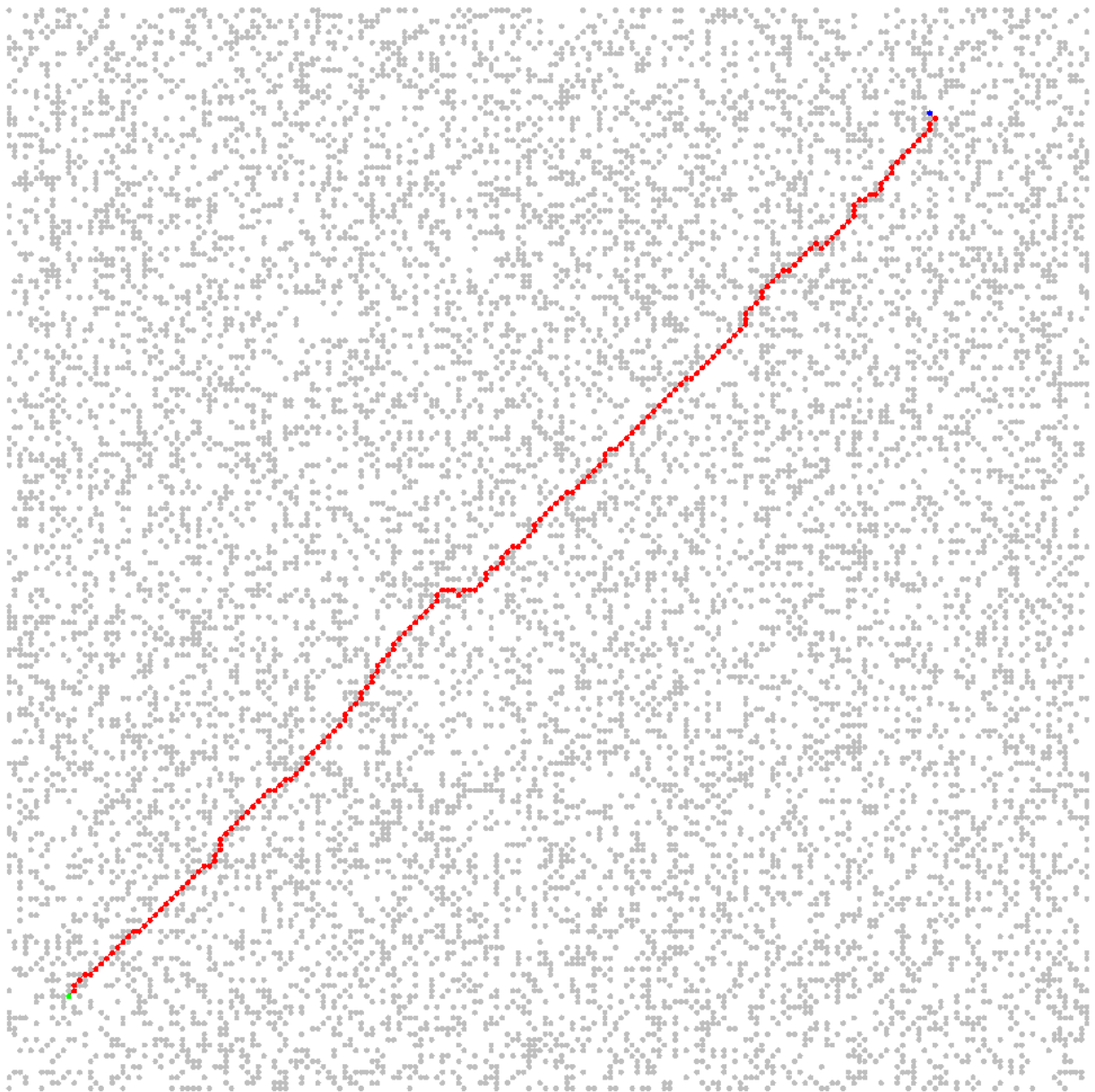170,180
Enter goal index e.g.: 0,0. Range is from (0,0) to (199,199).
11,17

Creating Environment...

Path Found

Time Taken: 48.0 milliseconds

Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
2

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
3

Enter starting index e.g.: 0,0. Range is from (0,0) to (199,199).
170,180
Enter goal index e.g.: 0,0. Range is from (0,0) to (199,199).
11,17

Creating Environment...

Path Found

Time Taken: 95.0 milliseconds

```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
3

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
1

Enter starting index e.g.: 0,0. Range is from (0,0) to (299,299).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (299,299).
299,299

Creating Environment...

Path Found

Time Taken: 82.0 milliseconds
```
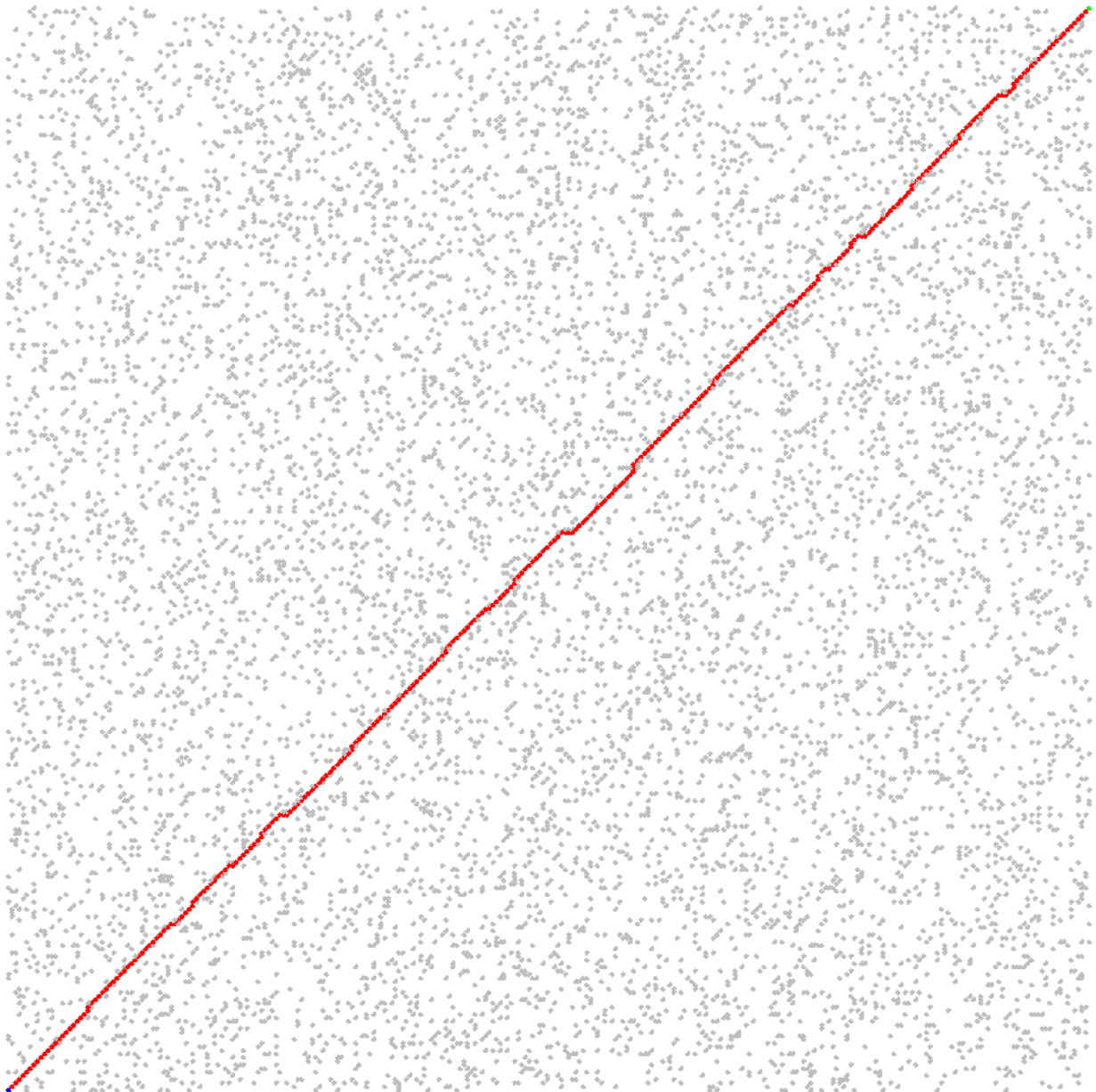
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
3

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
2

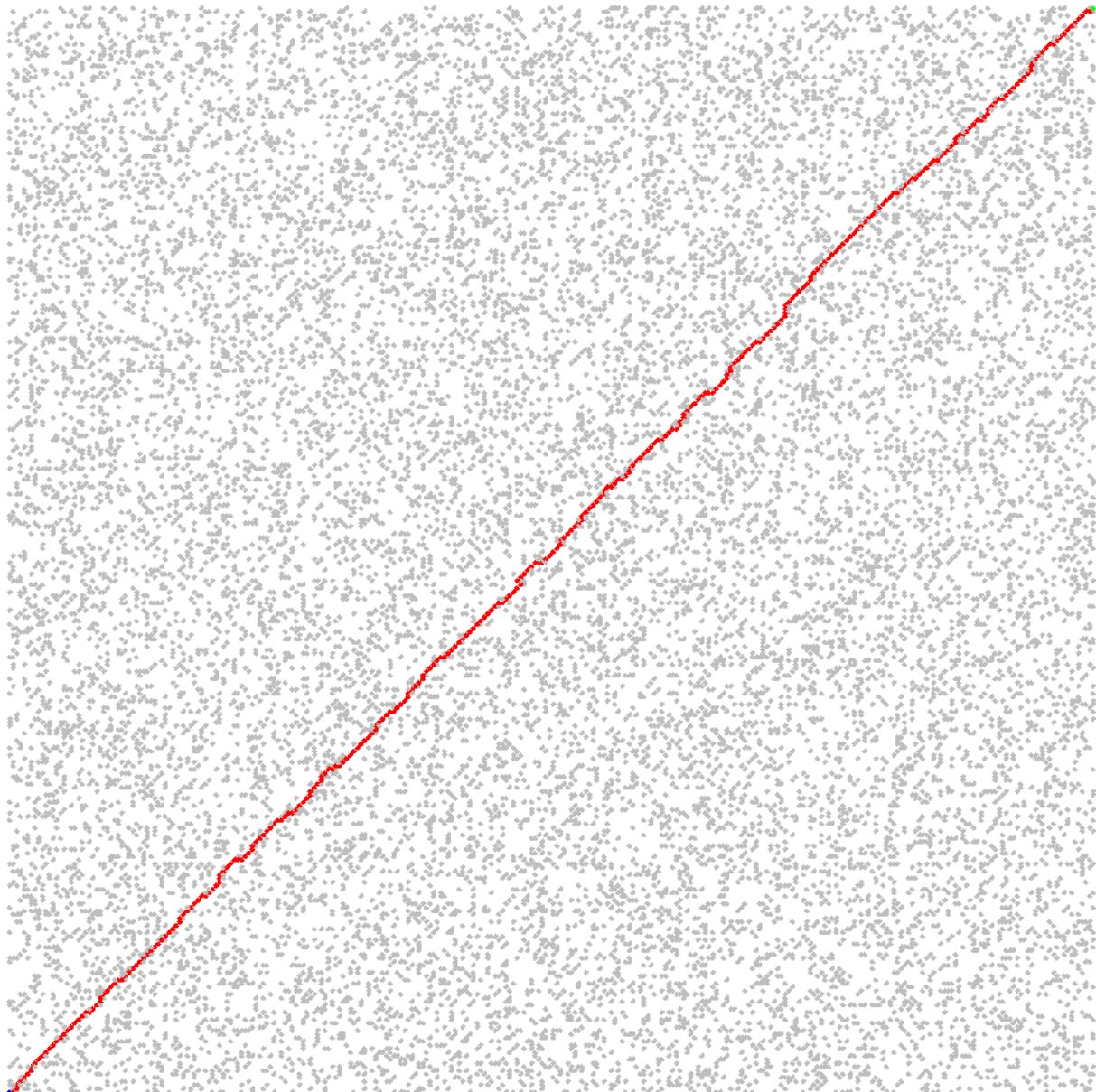Enter starting index e.g.: 0,0. Range is from (0,0) to (299,299).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (299,299).
299,299

Creating Environment...

Path Found

Time Taken: 88.0 milliseconds

```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
3

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
3

Enter starting index e.g.: 0,0. Range is from (0,0) to (299,299).
0,0
Enter goal index e.g.: 0,0. Range is from (0,0) to (299,299).
299,299

Creating Environment...

Path Found

Time Taken: 120.0 milliseconds
```
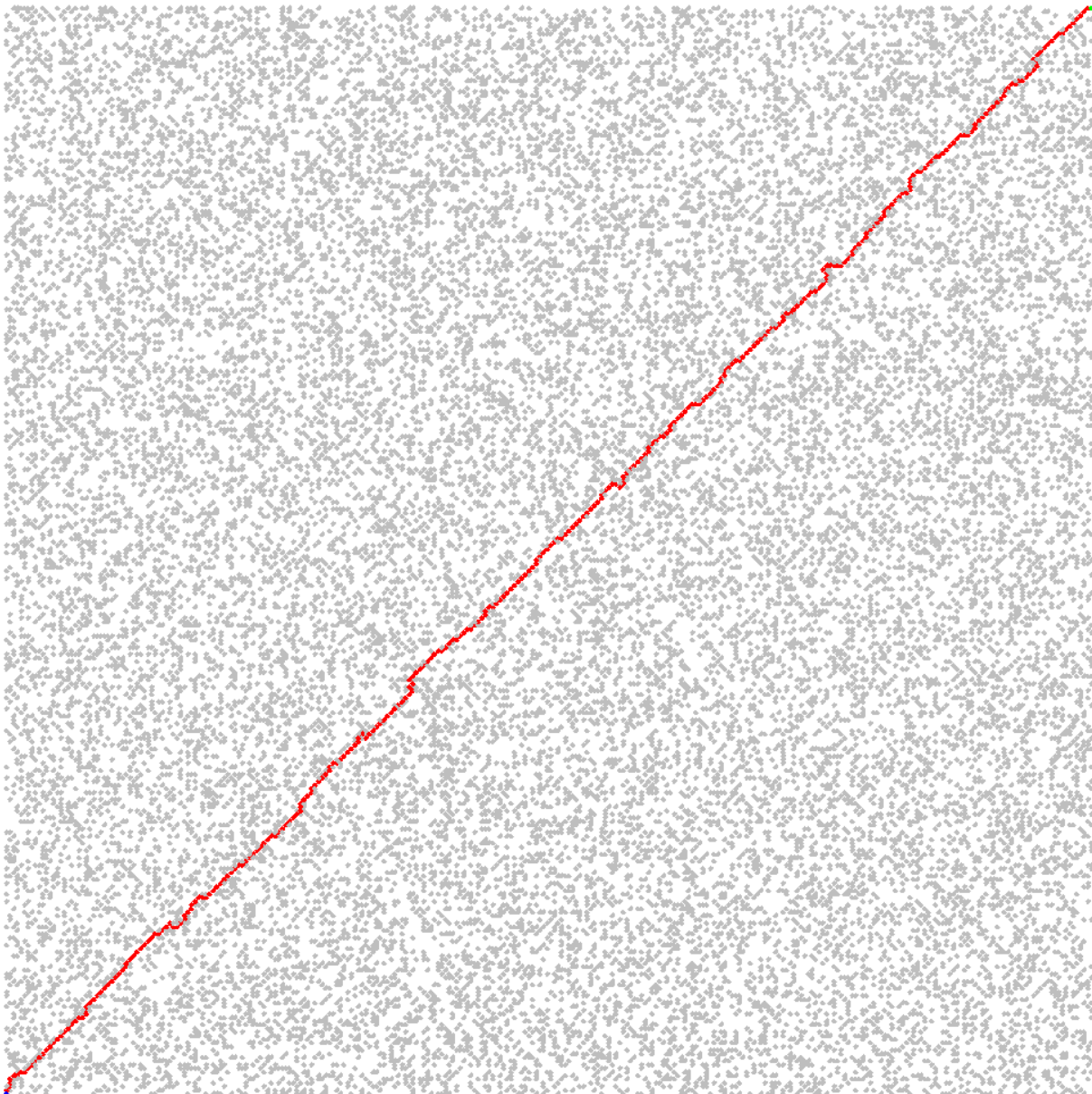
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
3

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
1

Enter starting index e.g.: 0,0. Range is from (0,0) to (299,299).
27,25
Enter goal index e.g.: 0,0. Range is from (0,0) to (299,299).
250,288

Creating Environment...

Path Found

Time Taken: 51.0 milliseconds
```

```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
3

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
2

Enter starting index e.g.: 0,0. Range is from (0,0) to (299,299).
27,25
Enter goal index e.g.: 0,0. Range is from (0,0) to (299,299).
250,288

Creating Environment...

Path Found

Time Taken: 58.0 milliseconds
```
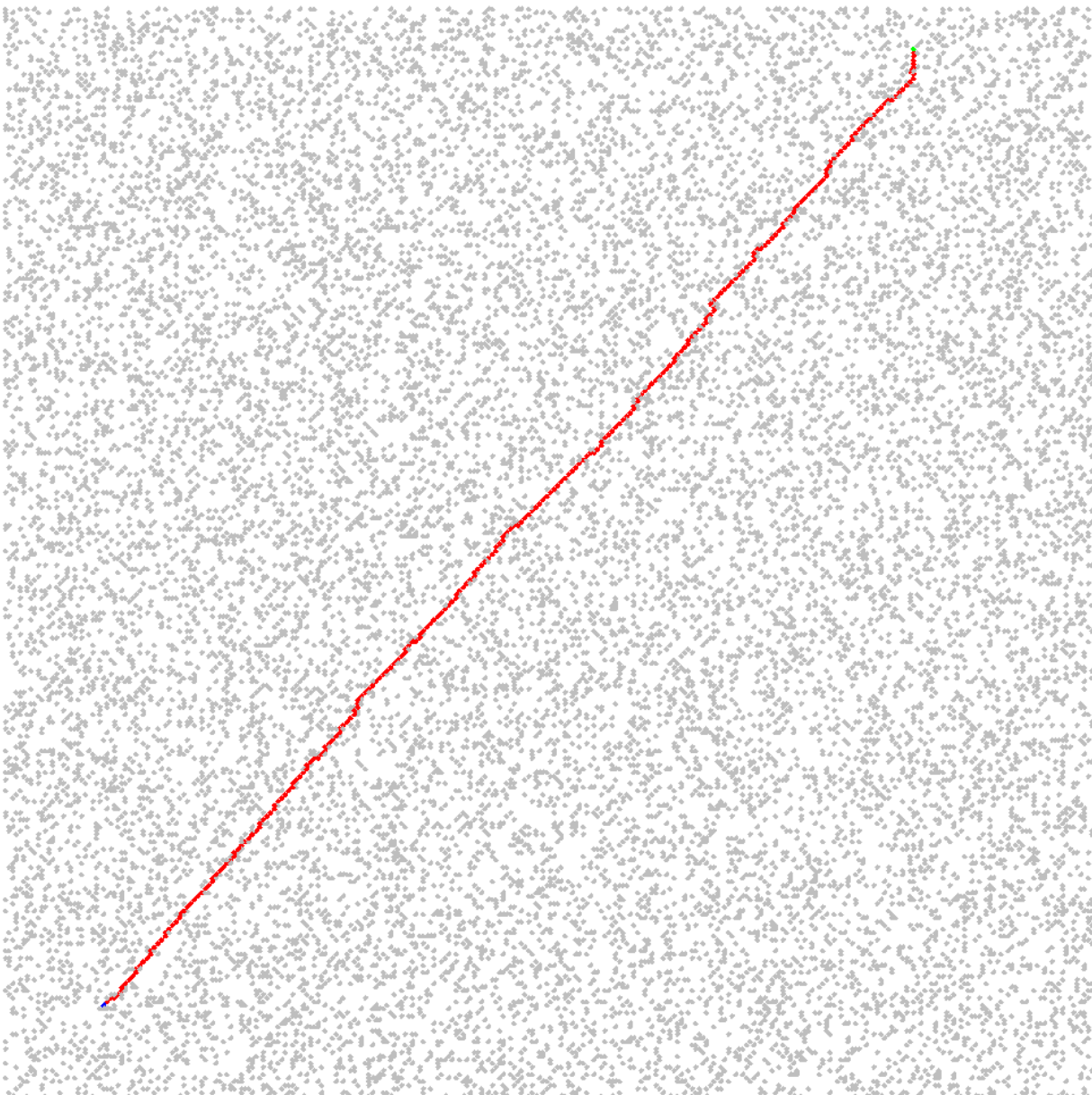
```
Enter 0 to Exit, 1 to run IQL
1

Enter which Environment you would like to test (1: 100x100 2:200x200 3:300x300)
3

Enter Obstacle Percentage (1: 10% 2:20% 3:30%)
3

Enter starting index e.g.: 0,0. Range is from (0,0) to (299,299).
27,25
Enter goal index e.g.: 0,0. Range is from (0,0) to (299,299).
250,288

Creating Environment...

Path Found

Time Taken: 87.0 milliseconds
```