Matthew Lai

README

To run simply input `‘./proj4 x y`’ where x and y are the target coordinates the robot should navigate to.

Should the `‘./proj4’` file be un-executable, simply run ‘`sudo chmod a+x ./proj4`’ *or* recompile the program with the following command:

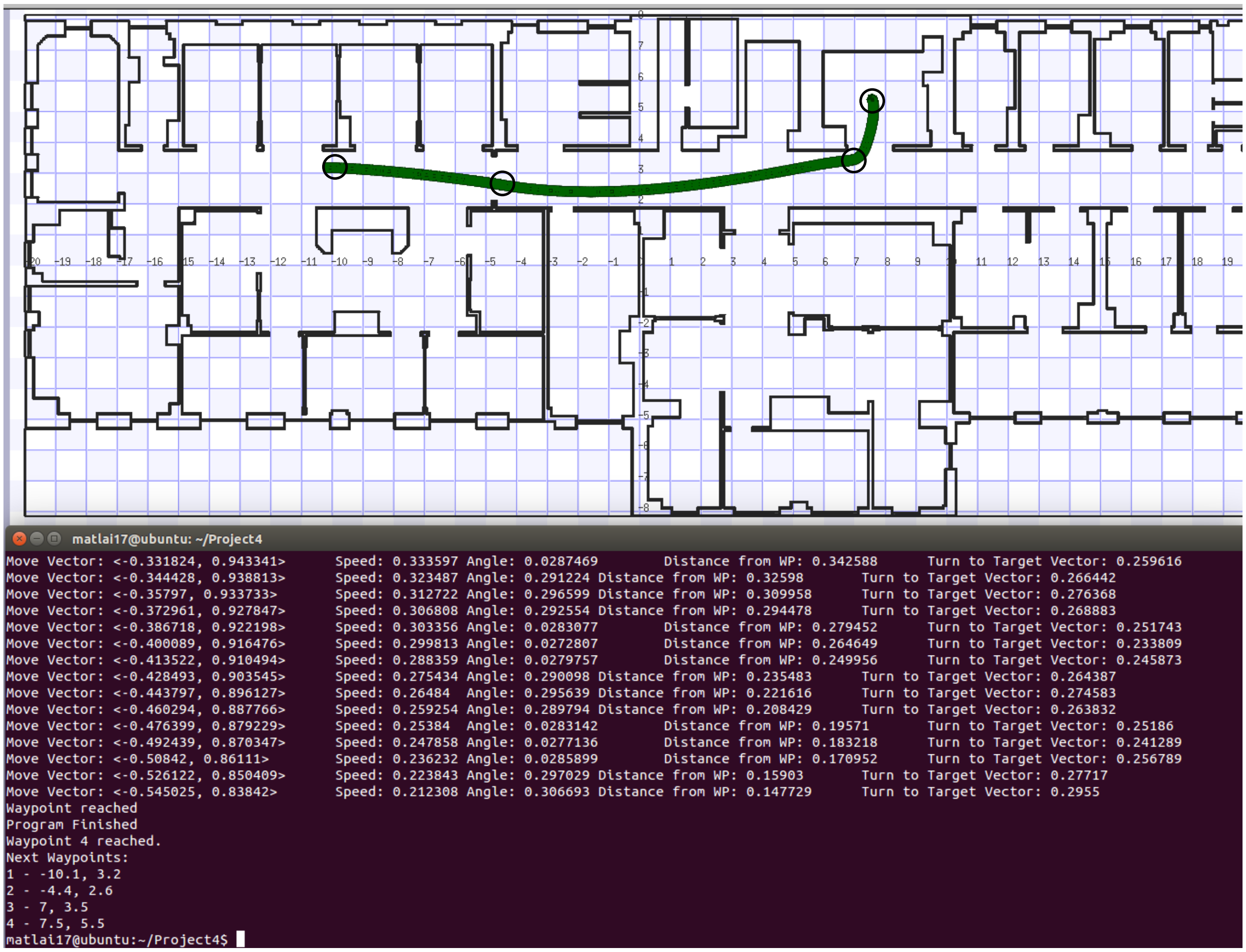
```
‘g++ -g -o proj4 $(pkg-config --cflags playerc++) proj4navigate.cc proj4.cc
proj4map.cc $(pkg-config --libs playerc++)’
```

This program has only been tested with the specific map and contains hardcoded variables that scales the program data structures to work with the hospital section map a certain scales. It may not work with other maps unless certain variables of the program are changed.

Project 4 Writeup

1. I experienced many problems with this project, most of which was my inexperience with C++. I didn't encounter very many behavioral problems with my robot's obstacle avoidance as it gave very tight wall hugging capabilities. The only doorways that the robot was not able to traverse was the three or four smallest ones. Otherwise, no other issues became evident in my testing. When the obstacle avoidance moved the robot off the path, the robot would generally recovery very quickly. There was a single instance of the robot catching itself into a "hook" that was present in the terrain, unable to escape. I accounted for the problem by increasing the obstacle growth. To account for the extra growth, I programmed the algorithm to dynamically scale the obstacle growth back if the obstacle was not traversable after the obstacle growth phase.
   - I implemented my grid map within the pnm to map generation code (proj4map.cc) as a float** object.
   - This object was passed to the Navigation code (proj4navigate.cc) where the walls of the map was grown as it was rewritten into a new float** pointer object. This was accomplished simply by taking the robot size and deciding how many coordinate spaces to enlarge the obstacles by. As the original map was looped through, I simply wrote in the correct values to the new map.
   - The next process was generating the heat map. I implemented a dual wave generator to decrease the resources needed. Each point, the origin and the target, received their own set of queues and sets that tracked which coordinates to expand the wave from next and which coordinates have been visited before, respectively. The algorithm simply pushed new neighboring coordinates into the queue as each coordinate was set to the correct heat value. This repeated until either a queue was empty, indicating no paths were available, or the waves encountered a value that was foreign, indicating that it had reached the other wave.
   - The next phase in generating a plan was to generate a list of grid points from the heat map. This was done by randomly selecting a direction to go from each square starting from the robot square. If the randomly selected square has not been visited before and has the correct next value, then it was selected as the next coordinate. If it reached a dead end and cannot advance, then it backtracks and adds the node to the doNotVisit set.
   - The next step is to smooth the grid points. This was a simple matter of checking the square above, below, left, or right of the target square as determined by the direction of the origin square. If there are not occupied coordinates in the correct adjacent space to the target coordinate, then the middle coordinate can be removed.
   - The final step is to reconvert the grid point coordinates system to the waypoint coordinate system. This is done with some simple math as the coordinate system is scaled by a factor of 10 to the waypoint system.

[-10.071 -3.186] -> [7.5, 5.5]

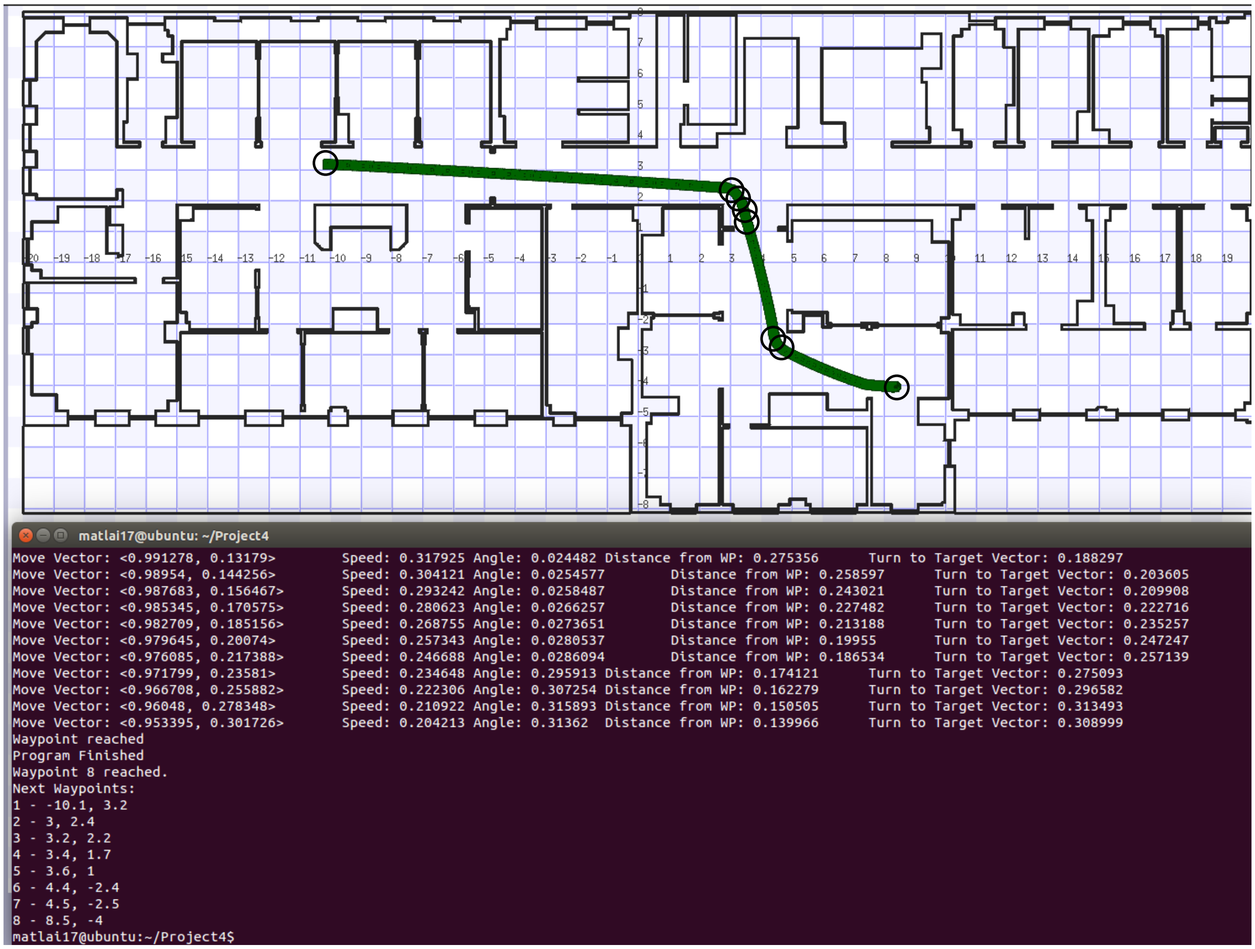


```
Move Vector: <-0.331824, 0.943341>      Speed: 0.333597 Angle: 0.0287469        Distance from WP: 0.342588      Turn to Target Vector: 0.259616
Move Vector: <-0.344428, 0.938813>      Speed: 0.323487 Angle: 0.291224 Distance from WP: 0.32598       Turn to Target Vector: 0.266442
Move Vector: <-0.35797, 0.933733>       Speed: 0.312722 Angle: 0.296599 Distance from WP: 0.309958      Turn to Target Vector: 0.276368
Move Vector: <-0.372961, 0.927847>      Speed: 0.306808 Angle: 0.292554 Distance from WP: 0.294478      Turn to Target Vector: 0.268883
Move Vector: <-0.386718, 0.922198>      Speed: 0.303356 Angle: 0.0283077        Distance from WP: 0.279452      Turn to Target Vector: 0.251743
Move Vector: <-0.400089, 0.916476>      Speed: 0.299813 Angle: 0.0272807        Distance from WP: 0.264649      Turn to Target Vector: 0.233809
Move Vector: <-0.413522, 0.910494>      Speed: 0.288359 Angle: 0.0279757        Distance from WP: 0.249956      Turn to Target Vector: 0.245873
Move Vector: <-0.428493, 0.903545>      Speed: 0.275434 Angle: 0.290098 Distance from WP: 0.235483      Turn to Target Vector: 0.264387
Move Vector: <-0.443797, 0.896127>      Speed: 0.26484  Angle: 0.295639 Distance from WP: 0.221616      Turn to Target Vector: 0.274583
Move Vector: <-0.460294, 0.887766>      Speed: 0.259254 Angle: 0.289794 Distance from WP: 0.208429      Turn to Target Vector: 0.263832
Move Vector: <-0.476399, 0.879229>      Speed: 0.25384  Angle: 0.0283142        Distance from WP: 0.19571       Turn to Target Vector: 0.25186
Move Vector: <-0.492439, 0.870347>      Speed: 0.247858 Angle: 0.0277136        Distance from WP: 0.183218      Turn to Target Vector: 0.241289
Move Vector: <-0.50842, 0.86111>        Speed: 0.236232 Angle: 0.0285899        Distance from WP: 0.170952      Turn to Target Vector: 0.256789
Move Vector: <-0.526122, 0.850409>      Speed: 0.223843 Angle: 0.297029 Distance from WP: 0.15903       Turn to Target Vector: 0.27717
Move Vector: <-0.545025, 0.83842>       Speed: 0.212308 Angle: 0.306693 Distance from WP: 0.147729      Turn to Target Vector: 0.2955
Waypoint reached
Program Finished
Waypoint 4 reached.
Next Waypoints:
1 - -10.1, 3.2
2 - -4.4, 2.6
3 - 7, 3.5
4 - 7.5, 5.5
matlai17@ubuntu:~/Project4$
```

Path Taken:

-10.1, 3.2
-4.4, 2.6
7, 3.5
7.5, 5.5

[-10.071 -3.186] -> [8.5, -4]

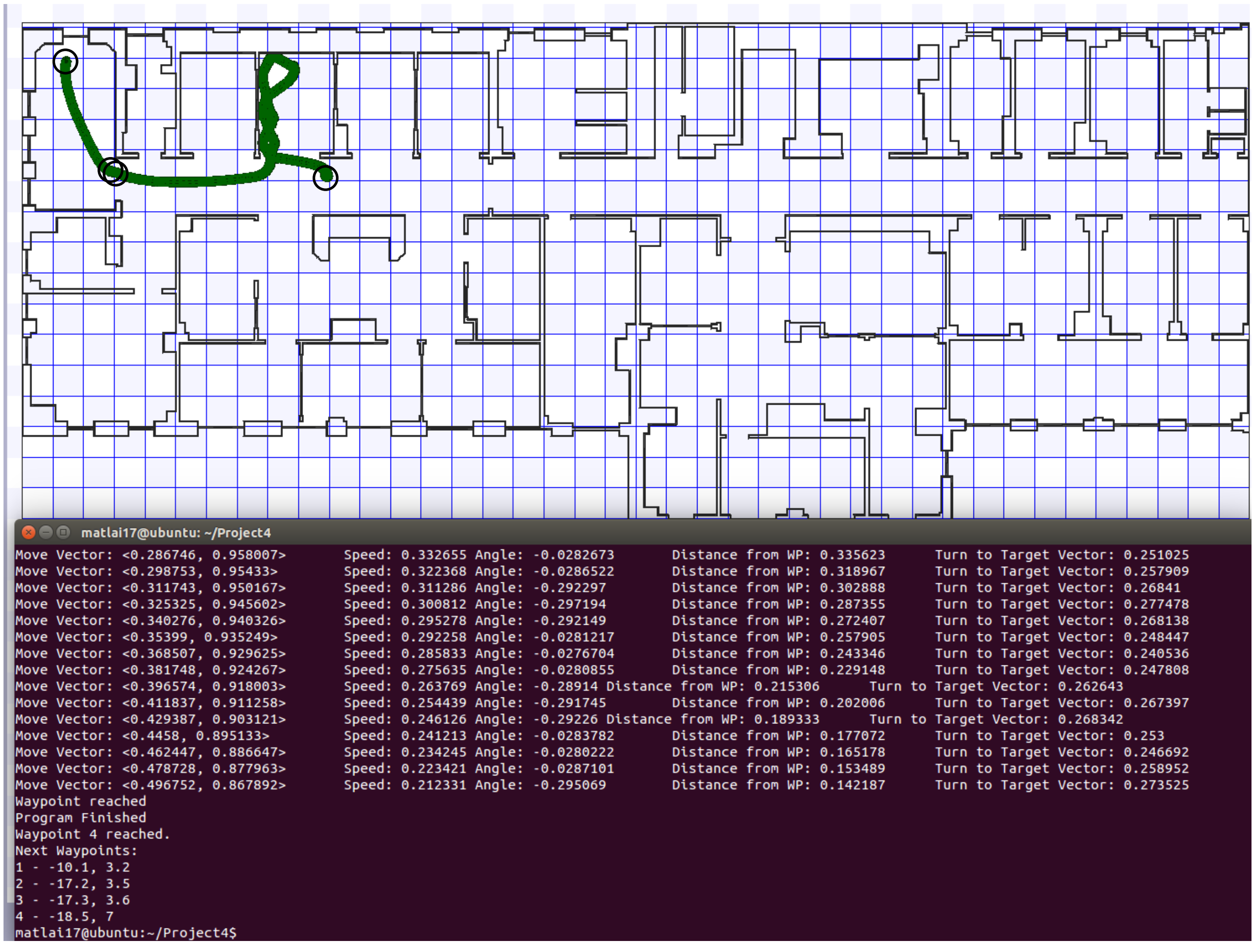


```
Move Vector: <0.991278, 0.13179>        Speed: 0.317925 Angle: 0.024482 Distance from WP: 0.275356      Turn to Target Vector: 0.188297
Move Vector: <0.98954, 0.144256>        Speed: 0.304121 Angle: 0.0254577        Distance from WP: 0.258597      Turn to Target Vector: 0.203605
Move Vector: <0.987683, 0.156467>       Speed: 0.293242 Angle: 0.0258487        Distance from WP: 0.243021      Turn to Target Vector: 0.209908
Move Vector: <0.985345, 0.170575>       Speed: 0.280623 Angle: 0.0266257        Distance from WP: 0.227482      Turn to Target Vector: 0.222716
Move Vector: <0.982709, 0.185156>       Speed: 0.268755 Angle: 0.0273651        Distance from WP: 0.213188      Turn to Target Vector: 0.235257
Move Vector: <0.979645, 0.20074>        Speed: 0.257343 Angle: 0.0280537        Distance from WP: 0.19955       Turn to Target Vector: 0.247247
Move Vector: <0.976085, 0.217388>       Speed: 0.246688 Angle: 0.0286094        Distance from WP: 0.186534      Turn to Target Vector: 0.257139
Move Vector: <0.971799, 0.23581>        Speed: 0.234648 Angle: 0.295913 Distance from WP: 0.174121      Turn to Target Vector: 0.275093
Move Vector: <0.966708, 0.255882>       Speed: 0.222306 Angle: 0.307254 Distance from WP: 0.162279      Turn to Target Vector: 0.296582
Move Vector: <0.96048, 0.278348>        Speed: 0.210922 Angle: 0.315893 Distance from WP: 0.150505      Turn to Target Vector: 0.313493
Move Vector: <0.953395, 0.301726>       Speed: 0.204213 Angle: 0.31362  Distance from WP: 0.139966      Turn to Target Vector: 0.308999
Waypoint reached
Program Finished
Waypoint 8 reached.
Next Waypoints:
1 - -10.1, 3.2
2 - 3, 2.4
3 - 3.2, 2.2
4 - 3.4, 1.7
5 - 3.6, 1
6 - 4.4, -2.4
7 - 4.5, -2.5
8 - 8.5, -4
matlai17@ubuntu:~/Project4$
```

Path Taken:

-10.1, 3.2
3, 2.4
3.2, 2.2
3.4, 1.7
3.6, 1
4.4, -2.4
4.5, -2.5
8.5, -4

[-10.071 -3.186] -> [-18.5, 7]

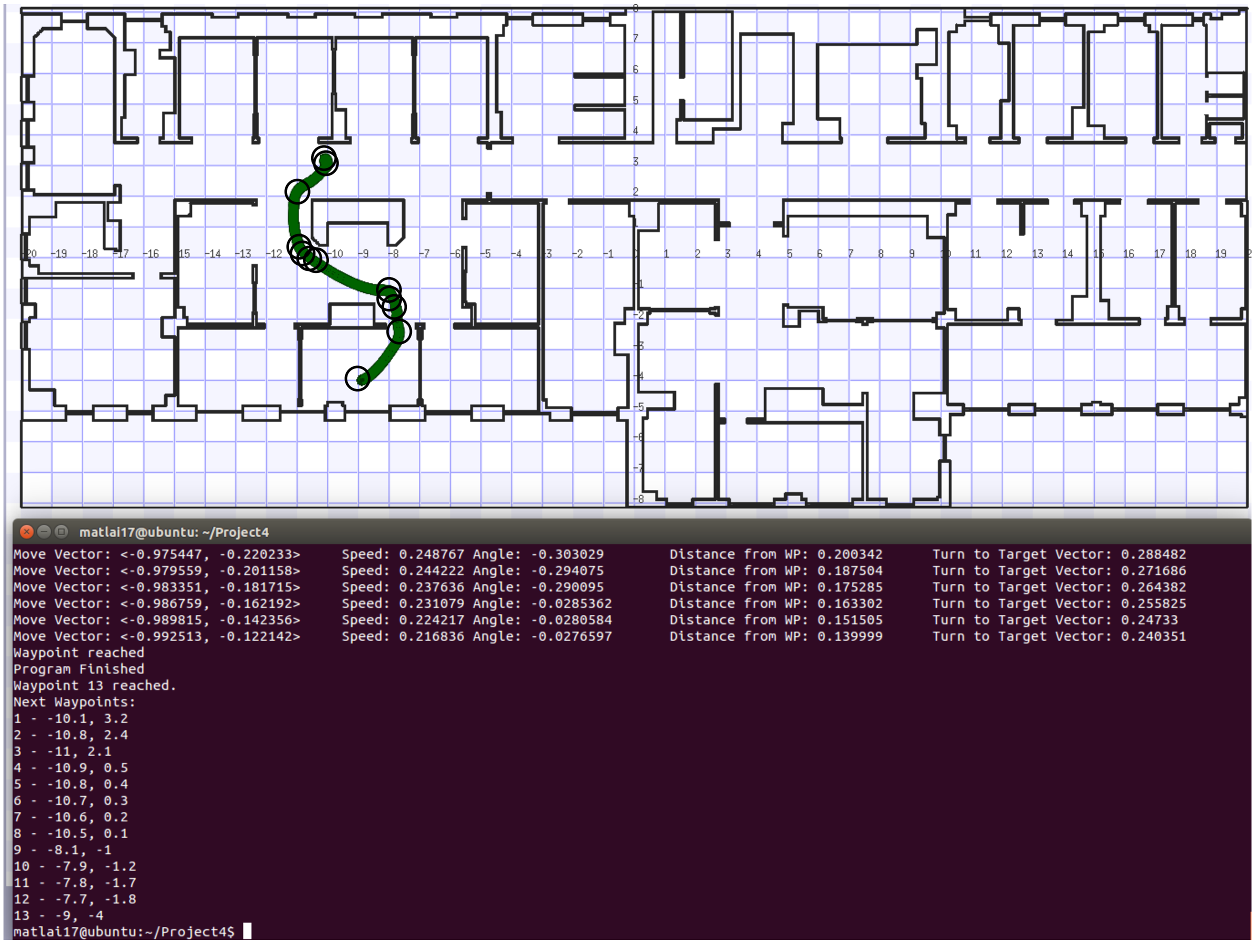


```
Move Vector: <0.286746, 0.958007>       Speed: 0.332655 Angle: -0.0282673       Distance from WP: 0.335623      Turn to Target Vector: 0.251025
Move Vector: <0.298753, 0.95433>        Speed: 0.322368 Angle: -0.0286522       Distance from WP: 0.318967      Turn to Target Vector: 0.257909
Move Vector: <0.311743, 0.950167>       Speed: 0.311286 Angle: -0.292297        Distance from WP: 0.302888      Turn to Target Vector: 0.26841
Move Vector: <0.325325, 0.945602>       Speed: 0.300812 Angle: -0.297194        Distance from WP: 0.287355      Turn to Target Vector: 0.277478
Move Vector: <0.340276, 0.940326>       Speed: 0.295278 Angle: -0.292149        Distance from WP: 0.272407      Turn to Target Vector: 0.268138
Move Vector: <0.35399, 0.935249>        Speed: 0.292258 Angle: -0.0281217       Distance from WP: 0.257905      Turn to Target Vector: 0.248447
Move Vector: <0.368507, 0.929625>       Speed: 0.285833 Angle: -0.0276704       Distance from WP: 0.243346      Turn to Target Vector: 0.240536
Move Vector: <0.381748, 0.924267>       Speed: 0.275635 Angle: -0.0280855       Distance from WP: 0.229148      Turn to Target Vector: 0.247808
Move Vector: <0.396574, 0.918003>       Speed: 0.263769 Angle: -0.28914 Distance from WP: 0.215306      Turn to Target Vector: 0.262643
Move Vector: <0.411837, 0.911258>       Speed: 0.254439 Angle: -0.291745        Distance from WP: 0.202006      Turn to Target Vector: 0.267397
Move Vector: <0.429387, 0.903121>       Speed: 0.246126 Angle: -0.29226 Distance from WP: 0.189333      Turn to Target Vector: 0.268342
Move Vector: <0.4458, 0.895133>         Speed: 0.241213 Angle: -0.0283782       Distance from WP: 0.177072      Turn to Target Vector: 0.253
Move Vector: <0.462447, 0.886647>       Speed: 0.234245 Angle: -0.0280222       Distance from WP: 0.165178      Turn to Target Vector: 0.246692
Move Vector: <0.478728, 0.877963>       Speed: 0.223421 Angle: -0.0287101       Distance from WP: 0.153489      Turn to Target Vector: 0.258952
Move Vector: <0.496752, 0.867892>       Speed: 0.212331 Angle: -0.295069        Distance from WP: 0.142187      Turn to Target Vector: 0.273525
Waypoint reached
Program Finished
Waypoint 4 reached.
Next Waypoints:
1 - -10.1, 3.2
2 - -17.2, 3.5
3 - -17.3, 3.6
4 - -18.5, 7
matlai17@ubuntu:~/Project4$
```

Path Taken:

10.1, 3.2
17.2, 3.5
17.3, 3.6
18.5, 7

[-10.071 -3.186] -> [-9 -4]



```
Move Vector: <-0.975447, -0.220233>     Speed: 0.248767 Angle: -0.303029        Distance from WP: 0.200342      Turn to Target Vector: 0.288482
Move Vector: <-0.979559, -0.201158>     Speed: 0.244222 Angle: -0.294075        Distance from WP: 0.187504      Turn to Target Vector: 0.271686
Move Vector: <-0.983351, -0.181715>     Speed: 0.237636 Angle: -0.290095        Distance from WP: 0.175285      Turn to Target Vector: 0.264382
Move Vector: <-0.986759, -0.162192>     Speed: 0.231079 Angle: -0.0285362       Distance from WP: 0.163302      Turn to Target Vector: 0.255825
Move Vector: <-0.989815, -0.142356>     Speed: 0.224217 Angle: -0.0280584       Distance from WP: 0.151505      Turn to Target Vector: 0.24733
Move Vector: <-0.992513, -0.122142>     Speed: 0.216836 Angle: -0.0276597       Distance from WP: 0.139999      Turn to Target Vector: 0.240351
Waypoint reached
Program Finished
Waypoint 13 reached.
Next Waypoints:
1 - -10.1, 3.2
2 - -10.8, 2.4
3 - -11, 2.1
4 - -10.9, 0.5
5 - -10.8, 0.4
6 - -10.7, 0.3
7 - -10.6, 0.2
8 - -10.5, 0.1
9 - -8.1, -1
10 - -7.9, -1.2
11 - -7.8, -1.7
12 - -7.7, -1.8
13 - -9, -4
matlai17@ubuntu:~/Project4$
```

Path Taken:

10.1, 3.2
10.8, 2.4
11, 2.1
10.9, 0.5
10.8, 0.4
10.7, 0.3
10.6, 0.2
10.5, 0.1
8.1, -1
7.9, -1.2
7.8, -1.7
7.7, -1.8
9, -4