

Northeastern University  
College of Engineering  
Department of Electrical and Computer Engineering  
EECE 2560: Fundamentals of Engineering Algorithms  
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Project: Autonomous Robot Package Delivery

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# Introduction

## Objectives & Goals

- To allow delivery vehicle to most efficiently deliver packages
- To enable robot to autonomously navigate obstacles
- To develop a robust backtracking algorithm that can be applied to other fields

## Project Scope

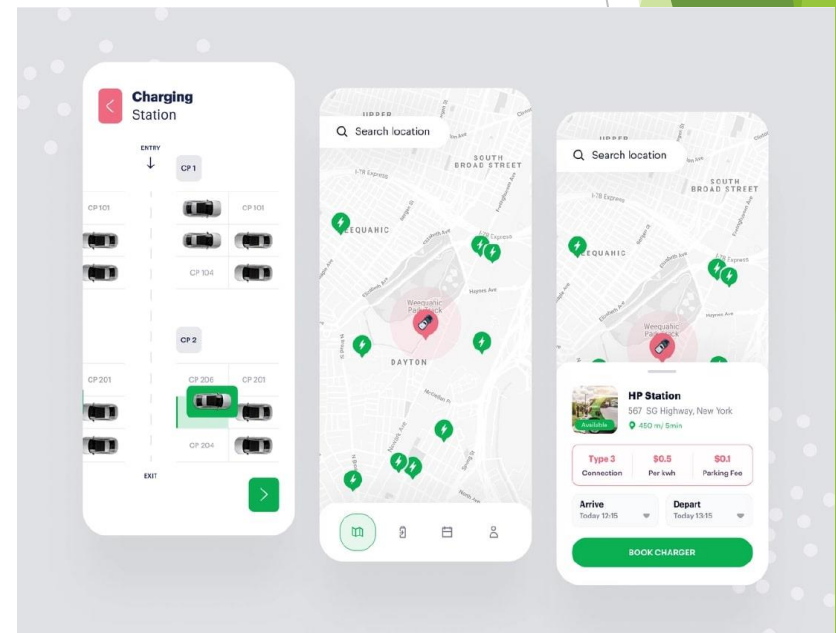
- Expand into greedy/graph algorithms by incorporating the car fueling along its path
- Incorporate the outputs onto a UI on a front-end web page

# Literature Review (Industry)



Amazon  
Delivery

Electric  
Vehicles

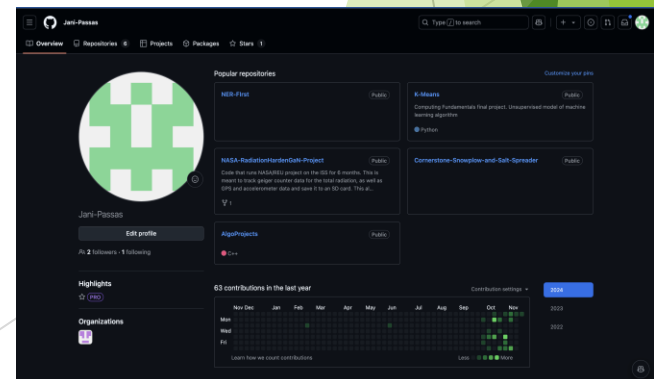
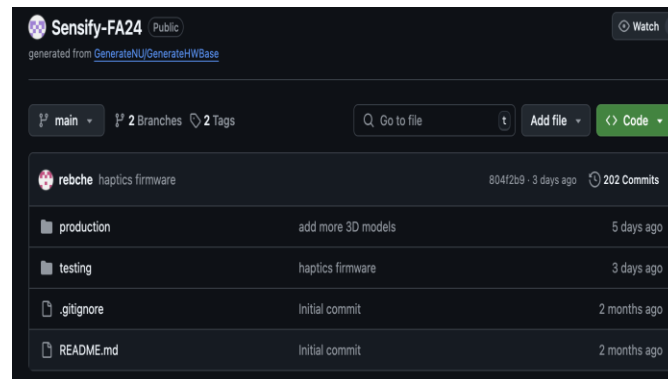
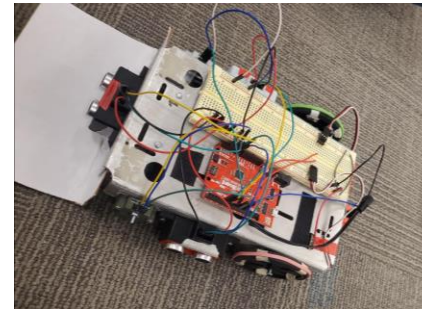
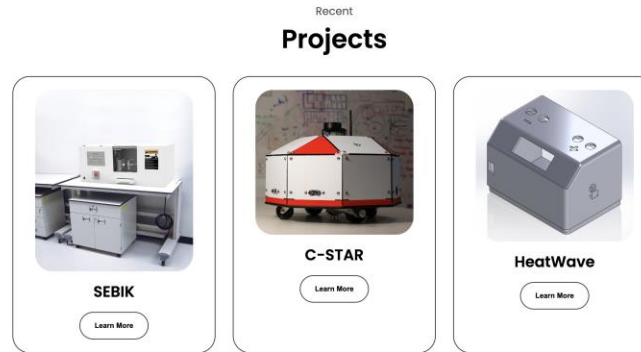


# Literature Review (Personal)

HTML &  
CSS

C++

Git



# Data Structures

## Structs

- Path
  - All paths including pathTaken
- Node
  - Weight and x, y coordinates. Used for priority queue

## Vectors

- 2D matrix of maze
- Used for path tracking
- Vector pair used for directions

## Queues

- Priority queue uses min-heap and greedy to always select smallest accumulated weight

# Methodology (2 approaches)

## Dynamic Programming

Recursively finds all paths

Then picks final path with minimum total weight

## Greedy

Prim's MST and Dijkstra's inspired

- Use priority queue/min-heap
- Tree vs start and end

Selects smallest current cumulative weight

## User Inputs

Maze, start/end, fuel



## Dynamic or Greedy Approach

Includes charging stations and obstacles



## Output

Terminal, CSV, and UI

# Back-end Overview

IsValid(x, y, maze)

- Check boundary constraints and if cell is an obstacle
- Returns true if valid, otherwise false

isValid:  $O(1)$

HasAdjacentCharger(maze, x, y, rows, cols)

- Check possible moves (up, left, down, right)
- If neighbors are within bounds and is a charger, return true

hasAdjacentCharger:  $O(1)$

PrintPath(finalPath, maze)

- For each cell in matrix  
If it is in path, print "1"  
If it's a charger on path or neighbor, print "C"  
If it's an unused charger, print "c"  
Else, print "0"

printPath:  $O(n*m)$

PathToCSV(pathTaken, filename)

- Open file with filename
- Iterate through rows and write the row into the file (comma separated)
- Close the file

printPath:  $O(n*m)$

# Back-end Overview (cont)

FindAllPaths(maze, x, y,  
currentPath, allPaths, curWeight,  
endX, endY)

- If out of bounds, return
- If destination, add path to allPaths with weight
- If cell already visited, return
- For each direction  
if newCell isValid, recursively call findAllPaths to explore deeper into path until destination reached or hit dead end

findAllPaths:  $O(4^{n*m})$

FindMinPath(allPaths)

- Initialize minPath
- For each path in allPaths, if path weight is less than minPath, then minPath = current path
- Return minPath

findMinPath:  $O(n*m)$

findGreedyPath(maze, startX, startY,  
endX, endY, greedyPath, fuel,  
maxFuel, fuelExhaustion)

- Initialize visited array, parent array, usedChargers array, and priority queue
- While priority queue not empty
  - Dequeue node with smallest weight
  - If destination, trace back to start using parent array
    - Mark path in greedyPath and return total weight
  - for each direction, move and check isValid and not visited.
    - Update weight, visit status, ad parent information.
    - Enqueue new cell into priority queue
- If destination not reached, return -1

findGreedyPath:  
 $O((n*m) \log(n*m))$   
Log from insertion in  
priority queue



## Analysis and Results (Backend)

# Dynamic Programming

- $O(4^{(n*m)})$

## Greedy Algorithm

- $O((n*m) \log(n*m))$

The image shows a C++ program in a text editor and a macOS memory warning dialog. The C++ code defines a 2D vector field and a function to find the minimum value in a 2D array. The memory warning dialog indicates that the system has run out of application memory and lists the memory usage of various applications.

```

1  Homework > C++ SampleRobotNavTesting.cpp | @ main()
2  93 void pathToCSV(vector<vector<int>>& pathTaken, string filename){
3
4      outfile << " ";
5
6      }
7
8      outfile << "\\n";
9
10     }
11     outfile.close();
12     cout << "Data saved into CSV file and written to: " << filename << endl;
13 }
14
15 int main(){
16     //Make to traverse, 0s are obstacles
17     vector<vector<int>> maze = {
18         {1, 0, 2, 3, 1, 3, 5, 2, 2, 1},
19         {2, 3, 1, 0, 2, 0, 2, 5, 3, 2},
20         {0, 2, 6, 4, 3, 4, 3, 2, 5, 1},
21         {1, 7, 2, 0, 1, 6, 4, 2, 1, 3},
22         // {1, 0, 2, 3, 1, 0, 0, 2, 3, 2},
23         {2, 3, 1, 0, 2, 1, 7, 2, 6, 1},
24         {0, 2, 6, 4, 3, 0, 2, 2, 4, 5},
25         {1, 7, 2, 0, 1, 1, 5, 2, 1, 0}
26     };
27
28     for(size_t i=0; i=maze.size(); i++){
29         for(size_t j=0; j=maze[i].size(); j++){
30             cout << maze[i][j] << " ";
31         }
32     }
33 }
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```

❏ TERMINAL
❏ janipassas@Janis-MacBook-Pro Homework % ./RobotNavCharge
1 0 2 3 1 3 2 -1 2 1 4 6 1 3
2 3 1 0 2 8 2 5 3 2 3 2 0 2
0 2 6 4 3 4 1 2 5 -1 3 2 3 0
1 7 2 0 1 6 4 2 1 3 6 2 5 3
1 0 2 3 1 0 0 2 3 2 3 1 3 5
2 3 1 0 6 -1 7 2 6 1 4 5 2 2
0 2 6 4 3 0 2 2 4 5 4 2 3 1
1 7 2 0 1 1 5 2 1 0 0 0 2 1
2 3 1 0 2 8 2 5 3 2 0 1 1 3
0 2 6 4 3 4 3 2 5 1 -1 3 4 5
1 7 2 -1 1 6 4 2 1 3 4 2 1 7
1 -1 2 0 1 0 -1 2 3 2 4 2 3 2
2 3 1 0 2 1 7 2 6 1 3 3 2 1
0 2 6 4 3 0 2 2 4 5 0 0 2 1

Boundaries for the input are 13 and 13
Please enter start coordinates (x y): 1 1
Please enter end coordinates (x y): 12 12
Please enter starting fuel: 15
Please enter max fuel capacity: 30
Please enter 1 for dynamic approach and 2 for greedy approach: 2
Minimum path weight: 49
Path traveled was:
0 0 1 1 1 1 1 C 0 0 0 0 0 0
0 1 1 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 0 C 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0 0 0
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0 C 0 0 0 0 C 0 0 0 0 0 1 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0

Remaining fuel: 19
Data saved into CSV file and written to: output.csv
❏ janipassas@Janis-MacBook-Pro Homework %

```

[illegible]

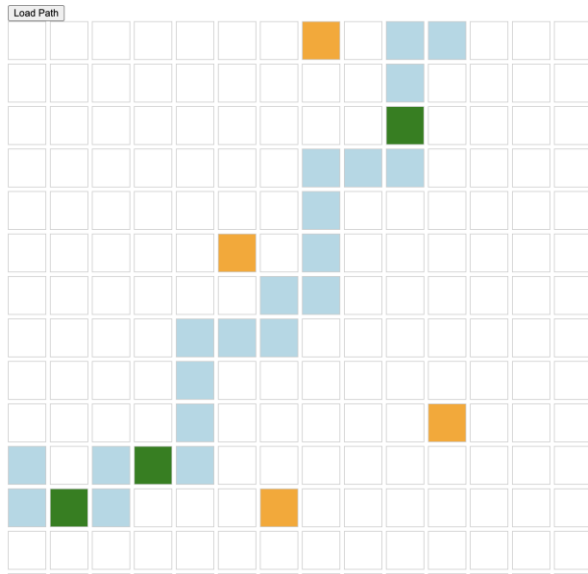
# CSV

# Analysis and Results (Frontend)

UI

HTML

## Backtracking UI



```
1 <!DOCTYPE html>
2 <html lang="en">
3 <head>
4   <meta charset="UTF-8">
5   <meta http-equiv="X-UA-Compatible" content="IE=edge">
6   <meta name="viewport" content="width=device-width, initial-scale=1.0">
7   <title>Pathfinding Maze Solver</title>
8   <style>
9     #gridContainer {
10       display: grid;
11       grid-template-columns: repeat(5, 40px);
12       gap: 2px;
13     }
14     .grid-cell {
15       width: 50px;
16       height: 50px;
17       border: 1px solid black;
18       display: flex;
19       justify-content: center;
20       align-items: center;
21       cursor: pointer;
22     }
23     .path-cell {
24       background-color: yellow;
25     }
26     .obstacle-cell {
27       background-color: grey;
28     }
29   </style>
30 </head>
31 <body>
32   <h1>Pathfinding Maze Solver</h1>
33   <div id="grid" class="grid"></div>
34   <button id="solveBtn">Find Shortest Path</button>
35 </body>
```

Server

```
vmalisetty_23@Vasishtas-MacBook-Pro AlgoProjects % python3 -m http.server
Serving HTTP on :: port 8000 (http://[::]:8000/) ...
```

# Frontend Continued

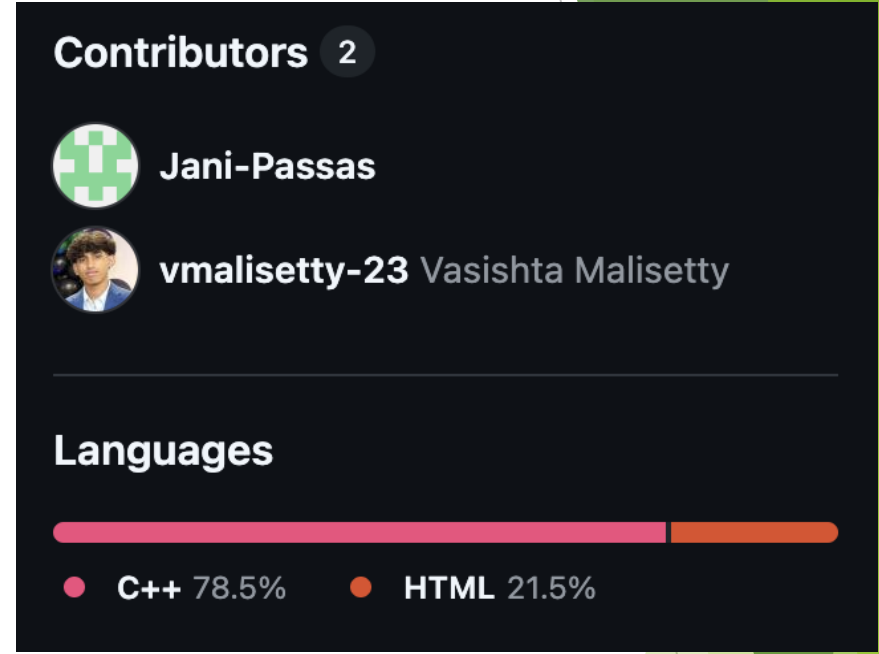
## LoadCSVFile()

- Fetch CSV file
- Parse the CSV files to get rows for the UI grid
- Time Complexity:  $O(n)$

## RenderGrid()

- If `grid == 1`, add block to path
- Else, do not add block to the path
- Time Complexity:  $O(n^2)$

# Analysis and Results (Git)



# Discussion

## Limitations

Based on an Ideal Environment

Not currently applicable to Real-World terrain

Memory space

## Applications

Energy Efficient Travel

Roomba/warehouse/delivery robotics

# Conclusion

## Conclusions



Greedy > Dynamic  
Programming



Successfully connected  
Frontend & Backend

## Future Steps



Develop fully responsive  
UI



Implement algorithm  
onto Real-World Terrain



Add charging stations  
for dynamic

# References

- ▶ [https://www.amazon.science/latest-news/the-science-behind-grouping-amazon-package-deliveries#:~:text=delivered%20on%20time.-,Customer%20Order%20and%20Network%20Density%20OptimizeR%20\(CONDOR\)%20has%20led%20to,to%20identify%20effective%20delivery%20options.](https://www.amazon.science/latest-news/the-science-behind-grouping-amazon-package-deliveries#:~:text=delivered%20on%20time.-,Customer%20Order%20and%20Network%20Density%20OptimizeR%20(CONDOR)%20has%20led%20to,to%20identify%20effective%20delivery%20options.)
- ▶ <https://www.sciencedirect.com/science/article/pii/S0142061524001522#:~:text=This%20method%20refers%20to%20the,current%20research%20presented%20in%20Ref>
- ▶ <https://www.geeksforgeeks.org/prims-minimum-spanning-tree-mst-greedy-algo-5/>
- ▶ <https://www.geeksforgeeks.org/rat-in-a-maze/>
- ▶ <https://www.geeksforgeeks.org/introduction-to-dijkstras-shortest-path-algorithm/>