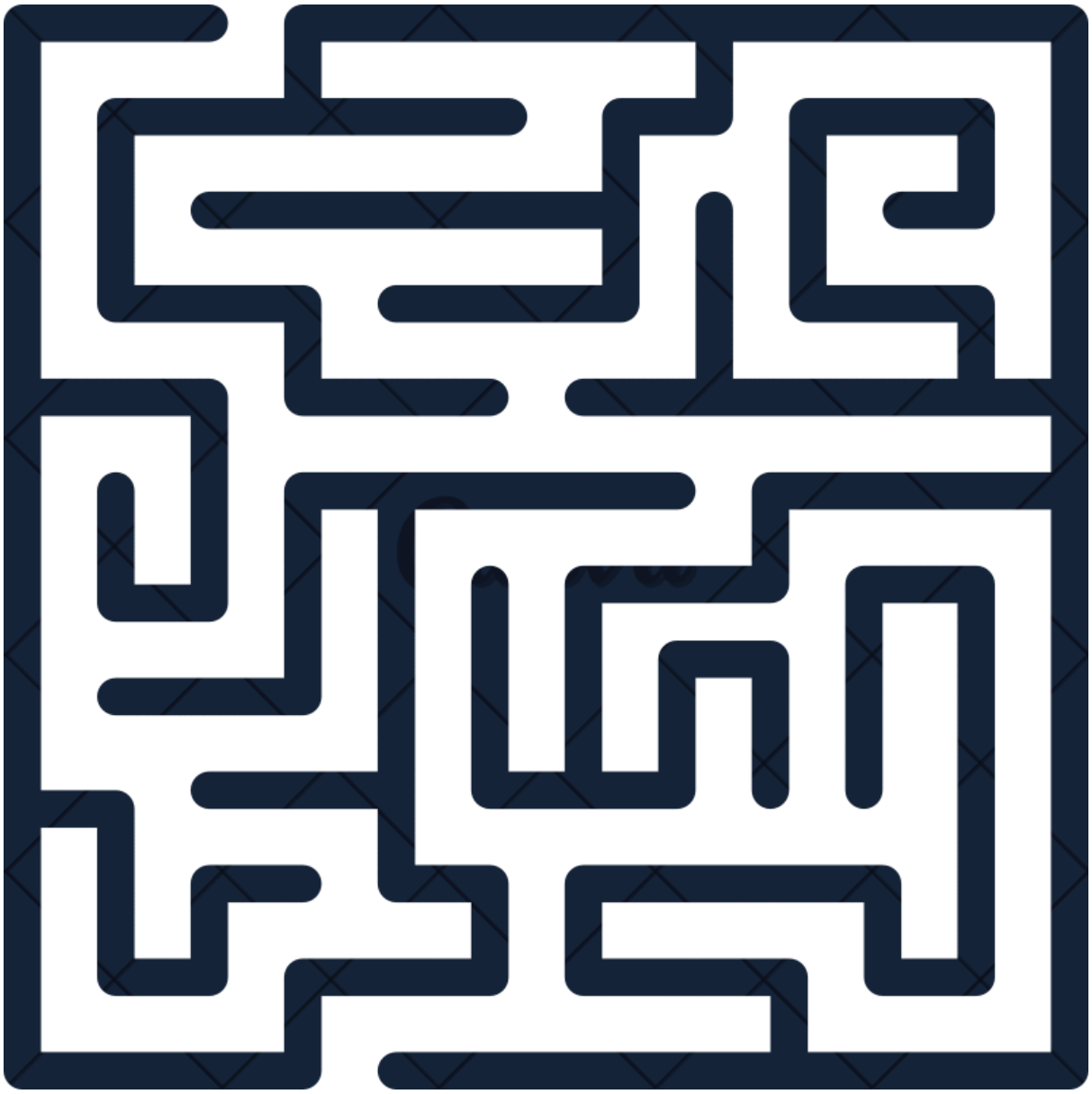
Pathfinding Visualiser



MUHAMMAD ABDULLAH

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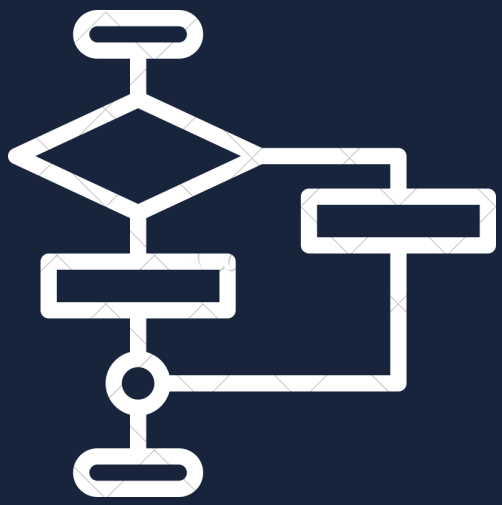
ANALYSIS

Intro

Overview

Pathfinding Visualizer is a software project developed in Python that provides an interactive tool to assist user's understanding of various pathfinding algorithms.



Within this stage of the project, the focus is on presenting a real problem with a comprehensive scope that is understandable to me and other third parties.

The project's requirements are documented with specific, measurable objectives that cover all required functionality. These requirements are established through dialogue with the users of the projectto ensure they meet their needs. The problem is also modeled effectively to be useful in subsequent stages of the project.

PURPOSE & USERS

Have you ever been lost trying to navigate through a maze or a city and wished there was an easier way to find the shortest or most efficient route? Pathfinding algorithms are the solution to this problem. They help us find the best route to take between two points by analyzing the connections between different paths.

However, understanding and visualizing these algorithms can be challenging. This is where a pathfinding visualizer comes in. It's a tool that helps us see how different pathfinding algorithms work and how they lead to different results. By inputting a start and end point, along with any barriers or obstacles, the visualizer generates a visualization of the pathfinding process, including the path that is found by the algorithm.

This tool can be used by anyone who is interested in learning about pathfinding algorithms, such as students, researchers, or developers. It can be used in educational settings, or as a tool for developing and testing pathfinding algorithms for various applications such as maze navigation, or video games. Overall, the project's main objective is to provide an interactive and effective learning tool for students and enthusiasts to learn and experiment with various pathfinding algorithms.

More specifically, this pathfinding visualizer can be useful for a wide range of users, including students in computer science, engineering, or mathematics, who are learning about algorithms and their applications. The tool can help them visualize and understand how different pathfinding algorithms work, which can be challenging to comprehend through theoretical learning alone.

Moreover, the tool can be useful for researchers who are exploring new pathfinding algorithms or improving existing ones. They can use the visualizer to test and compare the performance of different algorithms under various conditions and fine-tune them for specific applications.

Lastly, the tool can be used in educational settings, such as in classrooms or online courses, as a practical learning tool. Students can use it to practice implementing and testing pathfinding algorithms, improving their coding skills, and gaining hands-on experience in algorithm development.

Furthermore, pathfinding algorithms are essential in many real-world applications, including logistics, robotics, and transportation. For example, they can be used to find the shortest route for a delivery truck to follow, or to plan the most efficient path for a robot to navigate around obstacles in a factory.

Pathfinding algorithms come in different types, including examples such as Dijkstra's algorithm, A* algorithm, and Breadth-First Search (BFS). Each algorithm has its own advantages and disadvantages, depending on the problem at hand.

Using a pathfinding visualizer can also help users understand how different factors affect the pathfinding process. For instance, changing the weight or cost of certain paths or adding or removing obstacles can significantly impact the algorithm's results. This tool enables users to experiment with different variables and observe the resulting paths and algorithms' behaviors.

RESEARCH

To research the problem of pathfinding visualization, I started by conducting online research and reading relevant articles, academic papers, and forum discussions related to pathfinding algorithms and their visualization. I have also looked at existing pathfinding visualization tools and analyzed their features, functionality, and user feedback.

Through my research, I discovered that pathfinding algorithms are widely used in various domains such as robotics, gaming, and navigation systems. I also found that different pathfinding algorithms have their strengths and weaknesses, and the choice of algorithm depends on the specific problem domain and requirements. Some of the most commonly used algorithms are Breadth-First Search (BFS), Depth-First Search (DFS), Dijkstra's Algorithm, and A* Algorithm.

To develop a comprehensive understanding of the needs and expectations of potential users, I have conducted a questionnaire, tested current solutions, and interviewed a university student studying computer science.

The questionnaire was designed to gather insights into the user's preferences regarding the user interface, functionality, and performance of a pathfinding visualizer. The survey was distributed to a sample of individuals with varying levels of experience in computer science and pathfinding algorithms. The results of the survey helped me understand which features and functionalities are most important to users and helped me shape my objectives accordingly.

In addition to the questionnaire, I tested several existing pathfinding visualizers to gain a deeper understanding of their strengths and weaknesses. I compared features such as algorithm efficiency, ease of use, and visualization quality.

Finally, I conducted an interview with a university student studying computer science who has dealt with pathfinding algorithms before. The student provided valuable insights into his experience with pathfinding algorithms, as well as suggestions for improving the visualizer's usability and functionality. His expertise helped me adopt a refined approach to analysing the project.

INTERVIEW

1)**Me**: Can you tell me about your experience with pathfinding algorithms?

Student: Sure, I've worked with a few different algorithms in the past, including BFS, DFS, Dijkstra's, and A*. I've used them for various projects, such as implementing navigation systems in video games.

2)**Me**: That's great. What features do you think are important in a pathfinding visualizer?

Student: I think it's important to have a clear and intuitive user interface, as well as the ability to visualize the pathfinding process . It's also helpful to be able to adjust the speed of the visualization, so that users can see the process in more detail or in a shorter amount of time.

3)**Me**: What suggestions do you have for improving the usability of the visualizer?

Student: Having a good interactive UI complemented with a vibrant colour scheme can definitely ease usablity.

4)**Me**: Those are great suggestions. Is there anything else you'd like to see in a pathfinding visualizer?

Student: Something that could be useful is the ability to generate obstacles, so that users can test the algorithm's performance in a variety of scenarios or maby a maze to traverse through.

5)**Me**: What challenges would I encounterwhile developing the pathfinding visuliser?

Student: One challenge you may face is balancing the complexity of the algorithms with the usability of the tool. I would recommend to create a tool that is accessible to beginners, but also has enough depth to be useful for more advanced users.

6)**Me**: What features should I add in the project?

Student: To be able to set and remove start and end points, have industry known pathfinding algorithms such as Dijkstras, A*s, DFS and BFS. And most importantly visualizations of the algorithm's process and the final path .

Me: Thank you for your time and input. Will talk back with you shortly.

Based on the feedback received from the student, the project should have the following features:

- Visualization of the algorithm's process and the final path
- Four pathfinding algorithms: BFS, DFS, A*, and Dijkstra
- One maze generation algorithm
- The ability to set and remove start, end, and obstacle nodes
- Variable visualization speed
- An intuitive user interface that makes the user experience smooth and easy.

CURRENT SOLUTIONS

1

The **maze solver** website offers a user-friendly interface for generating and solving mazes with various algorithms. Users can customize the maze size and resolution and view the solving process through an animation. It allows users to experiment with different algorithms and settings to improve their understanding of maze solving algorithms.

Advantages:

- Provides a simple and intuitive user interface for generating and solving mazes.
- Offers a range of maze generation algorithms to choose from, allowing users to generate mazes of varying complexity.
- Provides different solving algorithms for users to experiment with, allowing them to compare the performance and efficiency of different algorithms.
- Allows users to customize the maze size and resolution, giving them greater control over the maze generation process.
- Generates animations of the solving process, making it easier for users to visualize and understand the algorithm's behavior.

Disadvantages:

- Limited options for customization, with only a few settings available to adjust.
- The website may be slow to generate and solve large or complex mazes, as the processing is done on the server-side.
- Only provides maze solving and generation tools, with no additional educational resources or explanations on the underlying algorithms.

2nd

VisuAlgo offers a pathfinding visualizer tool that lets users select from different algorithms, such as Dijkstra's algorithm and A* search. Users can modify the starting and ending nodes, as well as the obstacles' layout. The visualizer creates an animation of the algorithm, emphasizing the visited nodes, the shortest path, and any obstructions or barriers. The visualizer includes comprehensive instructions and explanations for each algorithm, making it an essential learning resource for educators and students.

Advantages:

- VisuAlgo offers a wide variety of visualizations for different algorithms, including pathfinding, sorting, searching, and more.
- The website is user-friendly and easy to navigate, with clear instructions and explanations for each visualization.
- Users can customize the inputs and settings for each algorithm, allowing for experimentation and a better understanding of the algorithms.
- The visualizations are interactive, allowing users to pause, step forward or backward, and speed up or slow down the algorithm's execution.
- The website offers educational resources and quizzes for each visualization, making it a valuable tool for students and educators.

Disadvantages:

- Some of the visualizations can be slow or laggy, especially for larger inputs or more complex algorithms.
- The website requires a stable internet connection to load and run the visualizations properly.
- While the website offers a wide range of visualizations, it may not cover all possible algorithms or variations, limiting its usefulness for more specialized applications.

3

Pathfinding.js is a JavaScript website specifically designed for pathfinding algorithms. It provides a range of common pathfinding algorithms, as well as options for customizing the input values and visualizations.

Advantages:

- The website supports a wide range of pathfinding algorithms, including Dijkstra's algorithm, A* search, and more.
- Users can customize the start and end points on the grid, as well as add and remove obstacles to see how the algorithms perform under different conditions.
- The visualizer generates an animation of the algorithm's execution, highlighting the path found by the algorithm and the nodes it visited along the way.
- The website provides detailed explanations of each algorithm, as well as their time and space complexities, making it a useful educational tool for students and educators.
- The website is open source, meaning that users can view and modify the source code for the visualizer to suit their needs.

Disadvantages:

- The website can be overwhelming for beginners due to the number of options and algorithms available.
- The visualizer can be slow at times, especially when generating and solving large grids.
- The website does not provide any interactive features for users to modify the code or customize the visualizer beyond the options provided(maze generation)

4

Cytoscape.js is a tool for visualizing and manipulating graphs it is best suited for experienced developers who need a versatile tool for visualizing and manipulating complex graphs. It may not be the best choice for those specifically interested in pathfinding algorithms, as other tools may provide more targeted and user-friendly visualizations..

Advantages:

- Wide range of customization options, including node and edge styling, layout algorithms, and interactive user controls.
- Can handle large graphs with many nodes and edges.
- Supports multiple file formats for importing and exporting graphs.
- Can be integrated with other web applications and frameworks.
- Provides a comprehensive documentation and API reference for developers.

Disadvantages:

- Requires programming knowledge and experience to use effectively.
- Not designed specifically for pathfinding algorithms and may not have the same level of visual feedback as other tools.
- May be overwhelming for beginners due to the many customization options and features.
- Performance may be slower on older or less powerful computers.

VISUALISERS IN GENERAL

Based on the current solutions I can derive some general positives and limitations of visualisers.

Positives:

Interactive learning: Pathfinding visualizers allow users to interact with the algorithms and see how they work in real-time. This can help users understand the algorithms better than simply reading about them.

Faster learning: Pathfinding visualizers provide a faster way of learning algorithms than traditional methods. With visual aids, users can quickly grasp complex concepts that would otherwise take longer to understand.

Easy experimentation: Pathfinding visualizers provide a platform for users to experiment with different parameters and inputs to see how they affect the algorithm's behavior. This makes it easier to understand the algorithm and its limitations.

Fun and engaging: Pathfinding visualizers are often designed with fun and engaging graphics and animations, making the learning process more enjoyable.

Limitations:

Simplified models: Pathfinding visualizers often simplify the algorithms to make them more accessible, which can sometimes lead to a lack of understanding of the algorithms' full complexities.

Limited problem scope: Pathfinding visualizers are often designed to solve a specific problem or set of problems, limiting their usefulness for solving other problems.

Lack of customization: Pathfinding visualizers may not allow for customization of the algorithm, limiting the user's ability to experiment with different approaches.

Dependency on technology: Pathfinding visualizers require access to a device with internet connectivity, which may not always be available.

QUESTIONNAIRE

Here is the feedback from the user group, along with the frequency of each response indicated in parentheses.

What is your experience level with pathfinding algorithms?
A. Beginner **(9)**
B. Intermediate **(4)**
C. Advanced **(2)**
D. Expert

RFQ: Asking about experience level with pathfinding algorithms helps me understand the level of knowledge of potential users, and adjust the visualizer accordingly.
WHID: Most survey respondents are beginners in pathfinding algorithms. This informs the need for clear explanations and visuals in the visualizer, and inclusion of basic algorithms such as BFS and DFS, along with more advanced ones like A* and Dijkstra's algorithm.

What are some use cases for pathfinding algorithms that you are interested in?
A. Transportation network optimization **(3)**
B. Robotics path planning **(5)**
C. Video game AI **(5)**
D. Other **(maps, selfdriving cars)**

RFQ: I am asking this question to understand the potential applications of the pathfinding visualizer, and to make sure it meets the needs of potential users.
WHID: From the survey, the majority of respondents are interested in using pathfinding algorithms for robotics path planning and video game AI.

How important is visual representation in understanding pathfinding algorithms?
A. Very important **(9)**
B. Somewhat important **(4)**
C. Not important

RFQ: This question is asked to gauge the importance of visual representation in understanding pathfinding algorithms.
WHID: More effort need to be put into making the visualization aspect of the tool more user-friendly and intuitive.

How would you like to interact with the visualization?
A. add and remove nodes **(8)**
B. Zoom in and out
C. Play, and speed control**(6)**
D. Other

RFQ: To gather information on the preferred user interaction methods for a pathfinding visualizer.
WHID: From the responses, it was discovered that the majority of users prefer the ability to add nodes, remove nodes, play visualisation and finally control the speed of visualisation.

What type of obstacles or barriers would you like to be able to add to the visualization?
A. Walls **(12)**
B. Weighted edges **(3)**
C. Other (please specify)

RFQ: Understanding the specific obstacles and barriers users would like to add to the visualization.
WHID: it seems that walls are the most popular obstacle, followed by weighted edges. Knowing this information, I can focus on incorporating walls as obstacles because its is majority voted.

Would you like to test the visualisation?
A. Yes (11)
B. No (4)

RFQ: To understand if the user would like to test the pathfinding visualization.
WHID: From the responses, it is clear that a majority of users would like to test the visualization. This information will be useful in determining any faults during the testing stage.

What is your preferred level of interactivity in the visualizer?
A. Minimal: algorithm, execution & no customization **(4)**
B. Medium: customize certain parameters eg. walls or speed **(7)**
C. High: Full control **(4)**

RFQ: To determine the preferred level of interactivity in the pathfinding visualizer.
WHID: Based on the responses, the majority of users prefer a medium level of interactivity, where they can customize certain parameters like walls or speed. This information will be used to design the visualizer with features that allow users to customize specific aspects of the visualization, while still maintaining a level of simplicity for those who prefer a more minimal experience.

Would you like to control the grid's dimensions?
A. Yes **(4)**
B. No **(7)**

RFQ: Inquiring if the user wants to control the grid's dimensions.
WHID: Majority do not want control over the dimensions.

When learning pathfinding algorithms such as Dijkstra's algorithm what did you struggle with? (Written Answers)

- Understand the concept and coding of the algorithm.
- Relate the terms to their respective parts with examples.
- Appreciate the algorithm by running through a small example.
- Grasp the concept of how it relates to graph theory.
- Overcome the difficulty in visualizing the algorithm.

RFQ: This question aims to gather insights on the common struggles that students face when learning pathfinding algorithms, specifically Dijkstra's algorithm.
WHID: From the answers provided, it seems that students generally face challenges when learning and conceptualising the algorithms

What other features or functionality would you like to see in a pathfinding visualizer? (Written Answers)

- A speed control button to adjust the speed of the animation
- Custom map import feature to upload own maps and images to the visualizer
- A red line showing the shortest path as the algorithm runs
- Custom maze creation options with varying sizes
- Incremental algorithm execution with a step-by-step approach

RFQ: This question is asked to gather opinions and suggestions from users on additional features or functionalities they would like to see in a pathfinding visualizer.
WHID: From the answers, I would implement a speed control button, custom maze generation, instead of the step by step i will add variable speeds which was also mentioned in the interview, and finally will have the final path visualised.

How many rowsXcolumns would for the grid?

- 1080p
- 160x160
- 50x50
- 100x100

RFQ: To determine the size of the grid wanted by the user.
WHID: I planned to make the visualiser as a window possibly around 800x800 pixels within that i think 50x50 cells wouldnt be too small or too large.

Howdo you want to be able to set and remove nodes?

- clicking(9)
- buttons(4)

RFQ: To determine how to set and remove nodes.
WHID: Will implement adding and removing nodes by clicking left and right mouse buttons.

PATHFINDING ALGORITHMS

This is based on research of current solutions and implementations of pathfinding algorithms found online. This research will be used to inform the algorithm objectives.

While there are many implementations of graph search, all of them have a core set of similar components:

- A graph which is an ordered-pair composed from a set of vertices and a set of edges.
- A search set containing verticies which we have seen but not visited.
- A visited set containing verticies which we have both seen and visited.

The graph search starts when we select a root and a target. Starting with the root as the current vertex we do the following:

1) Add the current vertex to the visited set.

2) Add all not-visited neighbors of that vertex to the search set.

3) If the search set is empty, or if we found the target we stop here.

4) Else we pick a vertex from the search set and go back to step 1.

Steps 1 through 3 are common to all forms of graph search. Step 4 is where they diverge, and you'll note that I didn't specify how to pick a vertex from the search set.

- If you treat the search set as a stack and pick in LIFO order you get DFS.
- If you treat it as a queue and pick in FIFO order you get BFS.
- If you treat it as a priority queue and pick based on accumulated weight you have Dijkstra's.
- If you treat it as a priority queue and pick based on accumulated weight + some heuristic you have A*.

Algorithms Explained

In computer science, an algorithm is a step-by-step procedure for solving a problem or achieving a particular outcome. In the case of pathfinding algorithms, the desired outcome is to find the cheapest path between two points in a graph or network.

The weight in this scenario refers to a measurable quantity associated with the edges connecting the nodes in the graph. This weight could represent time, distance, capacity, or cost, depending on the context of the problem being solved.

Dijkstra's Algorithm is a greedy algorithm that starts at the starting point and iteratively adds the closest unvisited node to a visited set. The algorithm then relaxes the weights of adjacent nodes to find the cheapest path to each unvisited node. This process continues until the algorithm reaches the destination node or all reachable nodes have been visited. Dijkstra's Algorithm is guaranteed to find the shortest path in a weighted graph.

The **A* search algorithm** combines Dijkstra's Algorithm's breadth-first approach with a heuristic function that estimates the distance between the current node and the destination node. This heuristic function guides the algorithm towards the destination node, making it more efficient than Dijkstra's Algorithm.

Breadth-First Search is a graph traversal algorithm that visits all the nodes at the current depth before moving to the next depth. In other words, it explores all the nodes that are a distance of one from the starting node before exploring all the nodes that are a distance of two, and so on. BFS is guaranteed to find the shortest path between two nodes in an unweighted graph.

Depth-First Search, on the other hand, explores as far as possible along each branch before backtracking. This algorithm can be implemented recursively or using a stack. DFS is useful when the goal is to explore all the possible paths between two nodes rather than finding the shortest path.

In summary, BFS and DFS are useful for pathfinding in different contexts, depending on whether the goal is to find the shortest path or explore all the possible paths. Dijkstra's Algorithm and A* search algorithm are useful for finding the cheapest path in a weighted graph, with A* being more efficient than Dijkstra's Algorithm due to the use of a heuristic function.

MAZE

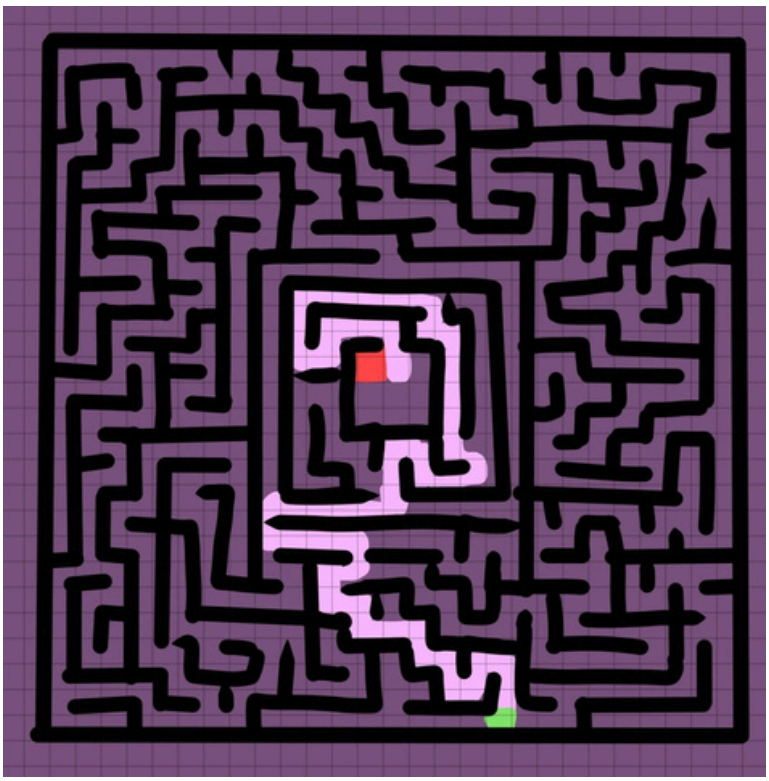
The **Recursive Division Method** is a popular algorithm for generating mazes. It works by recursively dividing a grid into smaller sub-grids and creating walls between them. Here's how it works:

- Start with a rectangular grid that has a wall around the outside and an entrance and exit.
- Choose a random point on one of the outside walls of the grid and create an opening. This will be the starting point for the maze.
- Divide the grid into two smaller sub-grids, either horizontally or vertically. This will create a wall between the two sub-grids.
- Choose a random point on the wall that was just created and create an opening. This will connect the two sub-grids and create a passage through the wall.
- Repeat steps 3 and 4 for each of the sub-grids, until the desired level of complexity is reached.
- If the sub-grids become too small, stop dividing them and fill in the remaining walls to complete the maze.

The **Recursive Division Method** produces mazes with long, winding passages and dead ends, making them a great challenge for pathfinding algorithms. By generating these mazes dynamically, the user can see how the pathfinding algorithms navigate through them in real time.

The image is a mockup sketched in Procreate, that showcases how the maze generation might look.

This feature can be accessed by clicking on the "Algorithms" button, however that is subject to change.



USER OBJECTIVES

- The user objectives for the pathfinding visualizer were carefully chosen based on the insights gathered from the interview, questionnaire responses, and existing solutions.
- The ability to define Start points, End points, and Walls was identified as a crucial requirement for the pathfinding visualizer based on the feedback received from the user group questionnaire responses. It was emphasized that users wanted the flexibility to define the start and end points of the search algorithm, which was also explicitly mentioned in the interview question 6. Walls were another commonly requested feature as they enable users to create obstacles in the grid, providing a more challenging search environment. This feature was also found in the current solutions, further highlighting its importance.
- The ability for users to remove any node (reset cell) was identified as a crucial requirement for the pathfinding visualizer based on feedback received from the questionnaire. Users indicated that the option to reset any cell would be helpful in modifying the search environment and ensuring ease of user interactivity. This requirement was also explicitly mentioned in the interview question 6 and has been implemented in the current solutions, further highlighting its importance.
- Users have the option to choose their preferred search algorithms from a selection that includes Dijkstra's, A*, BFS, and DFS. These particular algorithms were chosen based on their popularity within the pathfinding community and were specifically requested by the student in response to interview question 6. Furthermore, they are widely utilized in current solutions, making them a reliable and familiar choice for users.
- Users have the option to select their preferred visualization run speed from Fast or Slow. This requirement was identified based on user feedback from the questionnaire, which highlighted the importance of offering different visualization speeds to accommodate varying levels of experience. This need for flexibility in visualization speed was further emphasized in response to interview question 2, as the student expressed the desire to either observe the process in more detail or complete it within a shorter amount of time.
- Users have the option to create a maze within the pathfinding visualizer. This requirement was identified based on user feedback from the questionnaire, where users expressed a desire to generate mazes for testing the robustness of the algorithms and for creating a more challenging environment. Additionally, in response to interview question 4, users specifically requested the ability to create mazes, indicating its importance as a feature.
- Users can reset the grid within the pathfinding visualizer. This feature is derived from the ability to remove nodes, but with the addition of a dedicated reset button to enhance the user experience. The reset button allows users to quickly and easily clear the grid, providing a fresh starting point for creating new paths or testing different algorithms.
- Users have the ability to visualize the pathfinding process within the pathfinding visualizer. This requirement was identified based on user feedback from the questionnaire, where users expressed a desire to observe the algorithm in action and see how it finds the path from start to end point. Furthermore, in response to interview question 6, the ability to visualize the pathfinding process was specifically requested by the student, highlighting its importance as a feature. This functionality is also implemented in current solutions, further emphasizing its relevance.
- Users can view the final path from the start to end cell within the pathfinding visualizer. This requirement was added based on feedback from the questionnaire, where users expressed a desire to see the path found by the search algorithm. The importance of this feature was further highlighted in response to interview question 6, where the student specifically requested it. The functionality is currently available in existing solutions, demonstrating its relevance as a feature.

PROGRAM OBJECTIVES

1. Buttons
    a. **Left Mouse Click on grid**
        i. Set current coordinates as a start cell
        ii. if start already placed set target cell
        iii. if start and target already placed set wall cell
    b. **Right Mouse Click on grid**
        i. Reset cell and make it blank
    c. **Pathfinding Algorithms**
        i. 1)Add the start cell to the visited set.
        ii. 2) Add all not-visited neighbors of that cell to the search set.
        iii. 3) If the search set is empty, or if the target is found we stop here and go to step e(path).
        iv. 4) Else we pick a cell from the search set and repeat(go back to step 1).
        v. Dijkstras
            a. Treat the search set as a priority queue or any data structure that is based on priority, and you pick based on accumulated weight.
            1. A*
                a. Treat the search set as a priority queue or any data structure that is based on priority, and pick based on accumulated weight + some heuristic.
            2. BFS
                a. Treat the search set as a queue and pick in First In First Out order.
            3. DFS
                a. Treat the search set as a stack and pick in Last In First Out order.
        vi. Path
            1. If Path found
                a. Visualise the path from the start cell to the target cell
            2. If no path found and search set is empty
                a. Give an error message stating "There is no path to the end goal".
    d. **Maze**
        i. Develop a recursive division algorithm that creates a rectangular grid with an outside wall and an entrance/exit.
        ii. Ensure that the algorithm can divide the grid into two sub-grids with a wall between them, either horizontally or vertically.
        iii. Randomly choose a point on the wall between the sub-grids to create an opening that connects the two sub-grids.
        iv. Implement a mechanism to repeat steps 3 and 4 for each sub-grid until the desired complexity is achieved.
        v. Validate the maze using an algorithm to ensure that it is solvable and that there is at least one path from the entrance to the exit.
        vi. Incorporate a visual representation of the maze to aid in navigation and user experience
    e. **Visualise**
        i. Begin the search
        ii. Send the start cell to selected algorithm
        iii. Send the target cell to the selected algorithm
    f. **Clear**
        i. Reset every cell to blank
        ii. Reset cell neighbours
        iii. Reset Variables
    g. **Speed**
        i. Fast
            1. Limit to algorithm performace.
        ii. Slow
            1. Sleep system to 0.2 of a second

REQUIREMENTS

Based on the program objectives, I have identified and streamlined some key requirements so they look more organised.

Grid:
- Size
  - Width (800)
  - Height (800)
  - Rows (50)
  - Columns (50)

Cell Attributes:
- Position
  - x (int)
  - y (int)
- Start (bool)
- Wall (bool)
- Target (bool)
- Blank (bool)
- Waiting (bool)
- Visited (bool)
- Prior cell (cell)
- Distance (infinity)
- Neighbour cells (cells)
- g/f/h scores (int)

Buttons:
- Visualise(play)
- Clear(reset)
- Algorithms(drop down menue)
  - Dijkstra's
  - A* search
  - Breadth-First Search (BFS)
  - Depth-First Search (DFS)
- Speed(drop down menue)
  - Fast (System)
  - Slow (0.2)
- Maze
  - Recursive division
  -

Algorithms:
- Dijkstra's
- A* search
- Breadth-First Search (BFS)
- Depth-First Search (DFS)
- Recursive division(Maze)
- Backtracking(Path)

Data Structures:
- Stack
- Queue
- Priority Queue
- Array
- Multidimensional Array/List

USER OBJECTIVES SIMPLIFIED:

1. User can define Start points
2. User can define End points
3. User can define Walls
4. User can remove any node(reset cell)
5. User can choose their preferred search algorithms from:
   a. Dijkstras
   b. A*
   c. BFS
   d. DFS
6. User can choose the visualisation run speed from:
   a. Fast
   b. Slow
7. User can create a maze
8. User can reset the grid
9. User can visualise the pathfinding process
10. User can see the final path from Start to End cell

PROPOSED PROJECT DESCRIPTION:

- The visualizer will display a grid with nodes or cells representing individual points on the grid. The nodes can be either start or end, and some may be obstacles that cannot be traversed. The pathfinding algorithm works by analyzing the nodes on the grid and finding the shortest path from a starting point to an end point.
- When you first open the pathfinding visualizer, you will see a grid with a set of tools and options available. Which include algorithms to choose from, a maze creation button, algorithm speed button, visualise button, and a clear button.
- One of the first things you will need to do when using the pathfinding visualizer is to set a starting point and an end point. These can be selected by left clicking on the appropriate nodes on the grid.
- Once you have set the starting and ending points, you can begin the pathfinding process. To start the algorithm, you will need to select a search algorithm from a list of available options. The algorithms available are Dijkstra's algorithm, A* algorithm, breadth-first search (BFS), and depth-frist search. Each of these algorithms works in a slightly different way to find the shortest path between two points.
- Once you have selected an algorithm, you can start the pathfinding process by clicking the visualise button. The visualizer will then begin analyzing the nodes on the grid and finding the shortest path between the starting and ending points. As the algorithm works, you will usually be able to see the nodes that are being analyzed, as well as the path that is being traced between the starting and ending points.
- You can also be able to adjust the speed at which the algorithm runs. This can be useful for slowing down the process to better understand how the algorithm works, or for speeding it up to quickly find a solution.
- In addition to the basic pathfinding tools, you can create a maze by clicking the maze button before running the selected algorithm

This **prototype** was created in Procreate to make a visually appealing, minimalistic, and user-friendly UI.

The **sketch** shows different elements like buttons, grid, path, and nodes. The design emphasizes using a grid to make a consistent layout and easy-to-use buttons and nodes. A path is also used to guide users through the UI to minimize confusion.

The **prototype** aims to create an attractive and functional design by keeping it simple and minimalistic.

SYSTEM REQUIRMENTS

To run the pathfinding visualizer program on a computer, several hardware and software requirements need to be met. Firstly, an input device such as a keyboard and a mouse is required to interact with the program.

The keyboard is necessary to enter any necessary inputs, such as changing the settings, while the mouse is required to navigate through the program by clicking on the grid to place walls, start and end points, and buttons.

An output device such as a monitor is also necessary to display the user interface and the visualized path generated by the program. The monitor should be able to display at least 720p resolution for better visualization.

The program will also require a hard drive or any other form of storage device such as an SSD to store the executable file, minimum version of Python, and the Pygame library. At least 2GB of free space should be available on the storage device.

A processor with at least a dual-core x86 64-bit CPU (Intel / AMD architecture), equivalent or higher, is necessary to run the program smoothly. Additionally, a system with at least 2GB of memory is recommended to ensure the program runs without any issues.

The program requires Python version 3.2 or higher to run. Lastly, the program is compatible with Windows 7 or higher, Mac OS X 10.11 or higher (64-bit), and Linux: RHEL 6/7 (64-bit). Most libraries also work in Ubuntu.

It's important to note that while the pathfinding visualizer has been designed to work on machines with the specified minimum requirements, it may not run as smoothly or efficiently on those machines compared to higher end machines. This is because the minimum requirements are just that - the bare minimum needed to run the program.

Users running the program on machines with higher specifications may experience better performance and faster processing times. However, it's important to ensure that the program is still optimized to run efficiently on lower end machines to ensure accessibility for a wider range of users.

INPUT PROCESS STORAGE OUTPUT

Input: The input to the pathfinding visualizer is the user's interaction with the interface. The user can input the starting and ending points on the grid and can also add obstacles to the grid by clicking on cells. The input can also include the algorithm that the user wants to use to find the path between the start and end points.

Process: The process in the pathfinding visualizer involves the application of pathfinding algorithms to the data received from the user. When the user selects the start and end points, the program uses pathfinding algorithms like Dijkstra's algorithm, A* algorithm, or other algorithms to find the shortest path between the start and end points. The algorithm also takes into account any obstacles that the user has added to the grid.

Storage: The pathfinding visualizer stores the data about the grid, including the start and end points, obstacles, and the path generated by the algorithm. This data is stored in the computer's memory and is used to display the path on the screen. The pathfinding visualizer also stores any user preferences, such as the algorithm chosen and any visualization settings.

Output: The output of the pathfinding visualiser is the generated path between the start and end points. This output is displayed on the screen as a sequence of cells highlighted in a different color.

LANGUAGE

The project will be developed using Python and will have a user-friendly interface that allows users to specify the start and end points of the path, as well as any obstacles on the grid. Users will also be able to adjust parameters such as speed, maze selection and algorithm choices. The project will visualise different pathfinding algorithms in action, allowing users to compare their performance and efficiency in finding the shortest path.

Python is a widely-used, high-level programming language known for its simplicity, readability, and ease of use. It is commonly used in scientific, engineering, and data analysis fields. Python's efficiency is also essential for the project, as pathfinding algorithms can be computationally intensive. It can run on various platforms, including Windows, Mac, and Linux, making it easy to deploy the project on different devices and accessible to a wider audience.

The project is well-suited to Python due to its versatility, support for OOP, efficiency, and large community. The project provides users with a visual understanding of algorithms and allows experimentation with different maze densities to see how pathfinding algorithms perform in different scenarios.

The pathfinding visualizer can be run on any device that can run a Python Integrated Development Environment (IDE). This includes desktops, laptops, tablets, and any device as long as it can run a IDE . Users need to have a IDE installed on their device to use the visualizer, and there are many available for different operating systems.

DESIGN

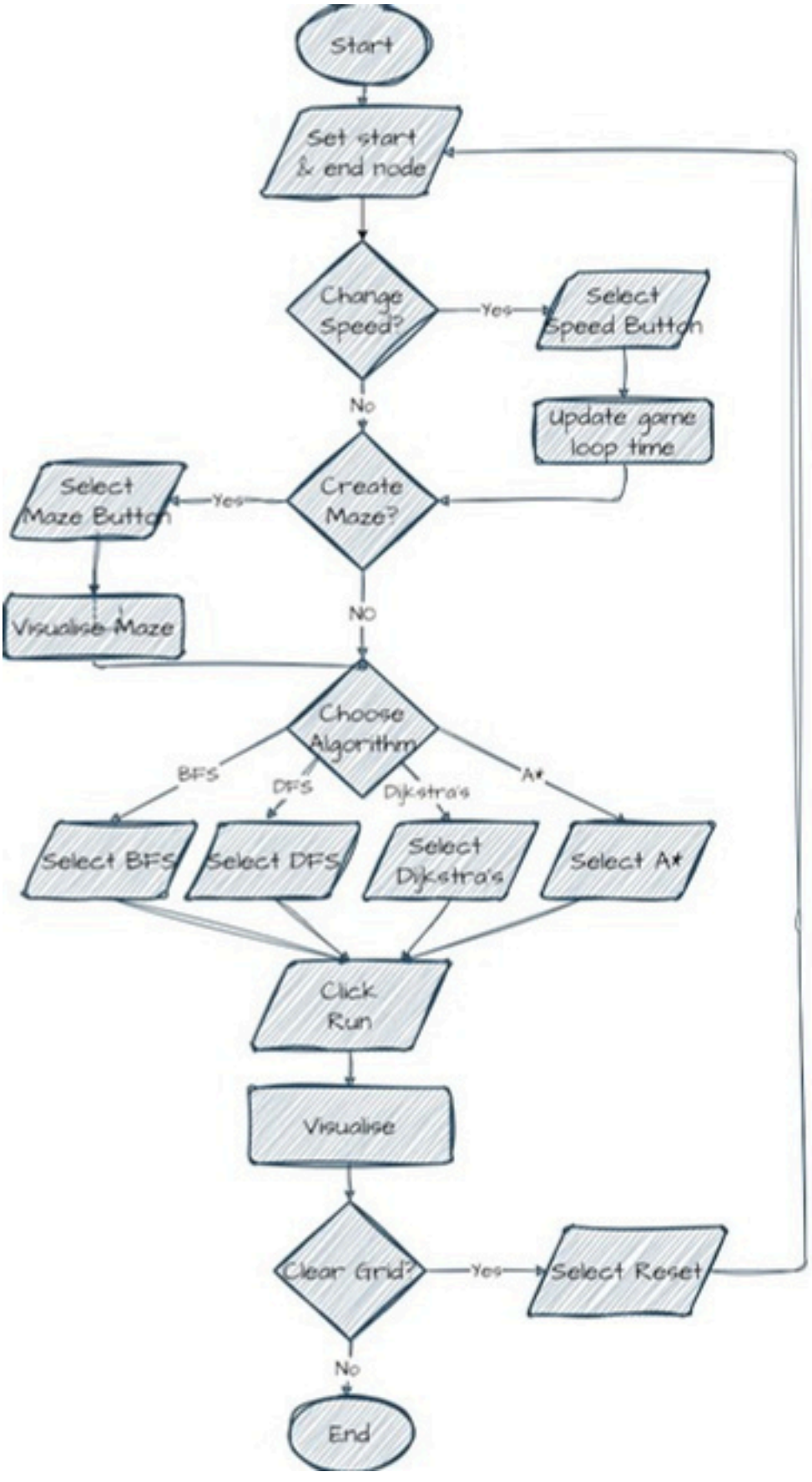
Intro

This section contains a fully articulated design for a pathfinding visualiser, and describes how all of the key aspects of the program are structured.

The visualizer is structured to provide users with a range of customization options, including the ability to plot start cells, end cells, and walls, adjust the visualization speed, and generate recursively generated mazes. Additionally, users can experiment with different inputs and parameters to gain a better understanding of the algorithms and their limitations.

The key features of the visualizer are presented in a user-friendly interface that includes a grid representation of the pathfinding problem, algorithm selection options, and a range of controls for customizing the visualizer's behavior. The interface has been designed to be intuitive and easy to use, making it accessible to users with varying levels of technical expertise.

SYSTEM DIAGRAM



SETTINGS & MODULES

The modules needed are:

messagebox from the tkinter library, which is used to display messages in a popup window.

pygame, is used to handle mouse input & game events.

sys, is used to handle the exit of the program.

random, is used to generate random numbers for the maze.

math, is used for math needed to get a heuristic for A* search.

time, is used to handle path visualisation timing.

Various settings are also needed, such as the size of the window, the number of rows and columns in a grid, and the width and height of each cell in the grid.

Additionally, there are several **colors codes** that are used to represent different states of the cells or buttons in the grid and a font to standardize the text used for the UI.

```
#Modules
from tkinter import messagebox, Tk
import pygame
import sys
import random
import math
import time

#settings
window_width, window_height = 800, 800
window_center = window_width/2
rows, columns = 50, 50
cell_width = window_width // rows
cell_height = window_height // columns

#cell colours
START = (0,128,0)
END = (255, 0, 0)
WALL = (33, 37, 41)
BLANK = (255,255,255)
VISITED = (172,58,74)
PATH = (205, 141, 0)
WAITING = (102,0,102)
INACTIVE_BUTTON = (33, 37, 41)
ACTIVE_BUTTON = (8, 8, 8)

#font
font = pygame.font.SysFont(None, 30)
```

DATA VOLUME

In the pathfinding visualiser, a certain amount of data is being stored and processed. The size of the window that the visualiser is displayed on is 800 x 800 pixels. This means that the visualiser can display a total of 640,000 pixels on the screen.

The grid that is used in the visualiser has 50 rows and 50 columns. This means that there are a total of 2500 cells in the grid. Each cell in the grid contains information about its current state, such as whether it is blocked or free for traversal.

As the user interacts with the visualiser by selecting start and end points or adding obstacles, this data is stored and processed by the program to generate the path between the start and end points.

The system requirements chosen for the pathfinding visualiser have been carefully selected to ensure that the program runs smoothly and efficiently on most modern computers. The specifications, such as the minimum RAM and processor speed, were chosen to provide a balance between performance and accessibility.

In terms of security, there are no sensitive data being stored in the program as it is simply storing information about the nodes on the grid such as their position, status (i.e. start, end, obstacle), and the distance from the start node. The program does not collect any personal information from the user and there are no login or authentication features that could potentially compromise the user's privacy or security.

QUEUE

Follows the **First In First Out** (FIFO) rule - the item that goes in first is the item that comes out first.

Basic Operations

- **Enqueue**: Add an element to the end of the queue
- **Dequeue**: Remove an element from the front of the queue
- **IsEmpty**: Check if the queue is empty
- **Size**: Check the size to see if the queue is full
- **Peek**: Get the value of the front of the queue without removing it(**Not required for the project**)

Complextiy

Enqueue and **dequeue** operations using an array have a constant time complexity of **O(1)**. However, if you use the **pop(N**) function in Python code, the time complexity might vary and become **O(n)** depending on the position of the item to be popped.

Psuedocode:

```
CLASS Queue:

    FUNCTION __init__():
        items <- []

    FUNCTION isEmpty():
        IF len(items)>0 THEN
            RETURN True
        RETURN False


    FUNCTION enqueue(item):
        items.insert(0,item)

    FUNCTION dequeue():
        RETURN items.pop()

    FUNCTION size():
        RETURN len(items)
```

- Used for **Breadth-First Search**
- **Queue** is **initialised** when the **visualise button** is pressed.
- **Queue resets** when **clear button** is pressed

Queue Dictionary:

Method	Description
__init__()	Constructor method to initialize an empty queue. It initializes the items attribute as an empty list.
isEmpty()	Returns a boolean indicating whether the queue is empty. It returns True if the length of the items list is greater than 0, and False otherwise.
enqueue(item)	Adds an element item to the end of the queue. It inserts the item at the beginning of the items list.
dequeue()	Removes and returns the element at the front of the queue. It removes the last element of the items list.
size()	Returns the number of elements in the queue. It returns the length of the items list.

Implementation:

Queue

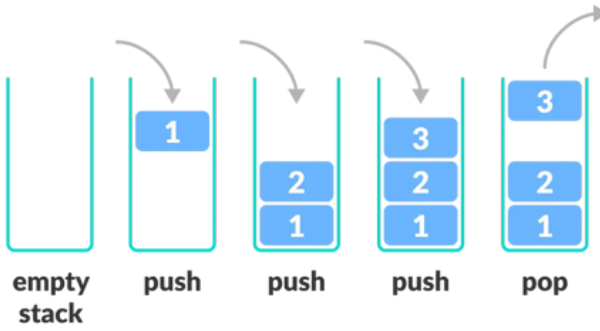
```
class Queue:
    def __init__(self):
        self.items = []

    def isEmpty(self):
        return self.items == []

    def enqueue(self, item):
        self.items.insert(0,item)

    def dequeue(self):
        return self.items.pop()

    def size(self):
        return len(self.items)
```

Queue

```
queue = Queue()
queue.enqueue(start_cell)
```

STACK

Follows the principle of **Last In First Out** (LIFO). This means the last element inserted inside the stack is removed first.



Basic Operations

- **Push**: Add an element to the top of a stack
- **Pop**: Remove an element from the top of a stack
- **IsEmpty**: Check if the stack is empty
- **Size**: Check the size to see if the stack is full
- **Peek**: Get the value of the top element without removing it

- Used for **Depth-First Search**
- **Stack** is **initialised** when the **visualise button** is pressed.
- **Stack resets** when **clear button** is pressed

```
Stack:
  - items: array to store the elements
  - top: index of the top element in the stack

  // Initialize an empty stack
  FUNCTION Stack()
      items <- []
      top <- -1

  // Add an element to the top of the stack
  FUNCTION Push(item)
      top <- top + 1
      items[top] <- item

  // Remove the top element from the stack and return it
  FUNCTION Pop()
      IF not IsEmpty()
          item <- items[top]
          top <- top - 1
          RETURN item

  // Check if the stack is empty
  FUNCTION IsEmpty()
      RETURN top == -1

  // Check if the stack is full
  FUNCTION Size()
      RETURN top + 1

  // Get the value of the top element without removing it
  FUNCTION Peek()
      IF not IsEmpty()
          RETURN items[top]
```

Stack Dictionary:

Method	Description
Stack()	Initializes an empty stack with an empty array and sets the top index to -1.
Push(item)	Adds an element to the top of the stack by incrementing the top index and assigning the new item to the items array at the new top index.
Pop()	Removes the top element from the stack and returns it. This is done by checking if the stack is not empty, assigning the value of the top element to a variable called item, decrementing the top index, and returning the value of item.
IsEmpty()	Checks if the stack is empty by comparing the value of top to -1. Returns true if the stack is empty and false if it is not.
Size()	Returns the size of the stack by returning the value of top plus one.
Peek()	Returns the value of the top element of the stack without removing it. This is done by checking if the stack is not empty and returning the value of the items array at the top index.

Implementation:

Stack

```
class Stack:
    def __init__(self):
        self.items = []

    def isEmpty(self):
        return self.items == []

    def push(self, item):
        self.items.insert(0,item)

    def pop(self):
        return self.items.pop(0)

    def peek(self):
        return self.items[0]

    def size(self):
        return len(self.items)
```

Stack

```
stack = Stack()
stack.push(start_cell)
```

PRIORITY QUEUE

Type of queue where elements have a **priority value**, and higher priority elements are served before lower priority ones. If two elements have the **same priority**, the one that was added to the queue earlier is served first.

Difference between Priority Queue and Normal Queue
In a queue, the **FIFO** rule is implemented whereas, in a priority queue, the values are removed **on the basis of priority**. The element with the highest priority is removed first.

Basic Operations

- **Insert**: Add an element in priority within the queue
- **Remove**: Remove an element with higheset priority from the queue
- **Size**: Check the size to see if the queue is full

- Used for **Dijkstras**
- **Queue** is **initialised** when the **visualise button** is pressed.
- **Queue resets** when **clear button** is pressed

```
// Initialize an empty priority queue
FUNCTION PriorityQueue(size)
    queue <- array of size
    count <- 0

// Add an element to the queue in priority order
FUNCTION Insert(item, priority)
    index <- count
    queue[index] <- (item, priority)
    count <- count + 1

FUNCTION remove() -> string:
    maxIdx <- 0

    // Iterate through the queue to find the element with the highest priority
    FOR i FROM 1 TO this.queue.Count-1:
       IF this.queue[i].priority > this.queue[maxIdx].priority:
          maxIdx <- i

    val <- this.queue[maxIdx].val

    // Shift all elements after the removed element to the left
    WHILE maxIdx < this.queue.Count - 1:
       this.queue[maxIdx] <- this.queue[maxIdx + 1]
       maxIdx <- maxIdx + 1

    this.queue.RemoveAt(this.queue.Count - 1)

    RETURN val


// Check the size of the queue
FUNCTION Size()
    RETURN count
```

Explaination:

- The priority queue is initialized with an empty array queue of size size and a counter count set to 0.
- The Insert function takes an item and its priority as input and adds it to the queue not in priority order.
- The Remove function removes and returns the element with the highest priority from the queue.
    - Finds the element with the highest priority by iterating through the queue and comparing each element's priority to the current highest priority.
    - Shifts all elements after the removed element one index to the left.
    - Returns the value of the removed element.
- The Size function returns the current number of items in the queue.

Implementation:

Queue

```
class PriorityQueue:
    def __init__(self):
        self.queue = []

    def insert(self, priority, val):
        self.queue.append((priority, val))

    def remove(self):
        max_idx = 0
        for i in range(1, len(self.queue)):
            if self.queue[i][0] < self.queue[max_idx][0]:
                max_idx = i
        val = self.queue[max_idx][1]
        while max_idx < len(self.queue) - 1:
            self.queue[max_idx] = self.queue[max_idx + 1]
            max_idx += 1
        priority = self.queue.pop()

        return priority[0], val

    def size(self):
        return len(self.queue)
```

Queue

```
pq = PriorityQueue()
pq.insert(0,start_cell)
```

DROPDOWN MENUE

The DropdownButton is a type of button that shows a list of options when clicked. It has a parameter called options that lists the options to choose from. When the button is clicked, the list of options appears on the screen. When the user selects an option, the list disappears and the selected option is saved.

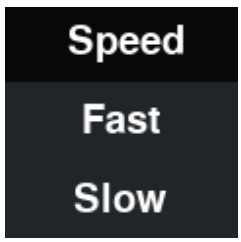
The DropdownButton can be customized to look and behave differently, but its main purpose is to make it easy for users to select an option from a list. It can be used in many types of applications, such as forms, menus, and settings screens.

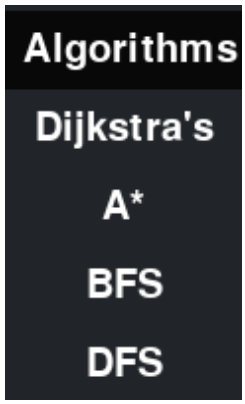
Used for

- **Algorithms**
  - Dijkstra's
  - A* search
  - BFS
  - DFS
- **Speed**
  - Fast
  - Slow

Psuedocode:

```
CLASS DropdownButton:

    FUNCTION __init__(self, options):
        SET self.options TO options
        SET self.selected_option TO None
        SET self.is_open TO False

    FUNCTION draw(self):

        # Draw the button
        draw_button()

        # Draw the menu IF it's open
        IF self.is_open:
            draw_menu()


    FUNCTION update(self, mouse_x, mouse_y, mouse_clicked):

        IF the mouse is over the button:
            # Mouse is over the button, show the menu
            SET self.is_open TO True

            FOR i, option IN enumerate(self.options):

                IF IF the mouse is over an option IN the menu:
                    # Mouse is over an option, highlight it
                    draw_highlighted_option()

                    # Check IF the user clicked on an option
                    IF mouse_clicked:
                        SET self.selected_option TO option
                        SET self.is_open TO False
        ELSE:
            # Mouse is not over the button, hide the menu
            SET self.is_open TO False

        # Return the selected option (if any)
        RETURN self.selected_option
```





Explanation

- The draw method draws the button and, if the dropdown menu is open, the menu options on the screen.
- The update method is responsible for handling user interactions with the widget, and takes in the current mouse position and mouse click state as arguments.
- If the mouse is over the button, the update method sets the is_open flag to True, indicating that the menu should be shown.
- If the mouse is over a menu option while the menu is open, the method highlights the option and checks if the user clicked on it.
- If the user clicks on a menu option, the selected_option attribute is set to the clicked option, the is_open flag is set to False, and the selected option is returned.
- If the mouse is not over the button or a menu option, the is_open flag is set to False and no option is selected.
- The selected_option attribute represents the currently selected option in the dropdown menu.
- The draw_highlighted_option method (not shown in the original pseudocode) highlights the currently hovered-over option in the menu.

Parameters Dictionary:

Parameter	Description
options	A list of strings representing the options to display in the dropdown menu.
selected_option	A string representing the currently selected option in the dropdown menu. Initialized to None.
is_open	A boolean flag indicating whether the dropdown menu is currently open or closed. Initialized to False.
mouse_x	The current x-coordinate of the mouse cursor on the screen.
mouse_y	The current y-coordinate of the mouse cursor on the screen.
mouse_clicked	A boolean flag indicating whether the left mouse button is currently clicked.

Implementation:

DropDown Button

```
class DropDown():

    def __init__(self, color_menu, color_option, x, y, w, h, font, main, options):
        self.color_menu = color_menu
        self.color_option = color_option
        self.rect = pygame.Rect(x, y, w, h)
        self.font = font
        self.main = main
        self.options = options
        self.draw_menu = False
        self.menu_active = False
        self.active_option = -1

    def draw(self, surf):
        pygame.draw.rect(surf, self.color_menu[self.menu_active], self.rect, 0)
        msg = self.font.render(self.main, 1, (255,255,255))
        surf.blit(msg, msg.get_rect(center = self.rect.center))

        if self.draw_menu:
            for i, text in enumerate(self.options):
                rect = self.rect.copy()
                rect.y += (i+1) * self.rect.height
                pygame.draw.rect(surf, self.color_option[1 if i ==
self.active_option else 0], rect, 0)
                msg = self.font.render(text, 1, (255,255,255))
                surf.blit(msg, msg.get_rect(center = rect.center))

    def update(self, event_list):
        mpos = pygame.mouse.get_pos()
        self.menu_active = self.rect.collidepoint(mpos)

        self.active_option = -1
        for i in range(len(self.options)):
            rect = self.rect.copy()
            rect.y += (i+1) * self.rect.height
            if rect.collidepoint(mpos):
                self.active_option = i
                break

        if not self.menu_active and self.active_option == -1:
            self.draw_menu = False

        for event in event_list:
            if event.type == pygame.MOUSEBUTTONDOWN and event.button == 1:
                if self.menu_active:
                    self.draw_menu = not self.draw_menu
                elif self.draw_menu and self.active_option >= 0:
                    self.draw_menu = False
                    return self.active_option
        return -1
```

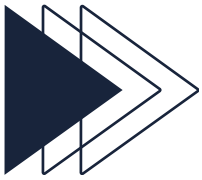
DropDown Button

```
algorithms = DropDown(
    [INACTIVE_BUTTON, ACTIVE_BUTTON],
    [INACTIVE_BUTTON, ACTIVE_BUTTON],
    5, 4, 120, 40,
    font," Algorithms",
    ["Dijkstra's", "A*", "BFS", "DFS"])

speed_menue = DropDown(
    [INACTIVE_BUTTON, ACTIVE_BUTTON],
    [INACTIVE_BUTTON, ACTIVE_BUTTON],
    130, 4, 120, 40,
    font," Speed",
    ["Fast", "Slow"])
```

BUTTON

Used for

- Maze
- Visualise(run)
- Clear(reset)



- The Button class has a draw_menu boolean variable and an active_option variable.
- The draw() method draws either the button or the menu options on the screen, depending on the value of draw_menu.
- The update() method checks the position of the mouse and updates the button's appearance and the menu's draw_menu flag accordingly.
- If the user clicks on the button, the draw_menu flag is toggled.
- If the user clicks on a menu option, the draw_menu flag is turned off, and the selected option is stored in the active_option variable.
- If the user clicks elsewhere, the draw_menu flag is turned off without selecting any options.

Psuedocode:

```
DEFINE FUNCTION update(self, mouse_x, mouse_y, click):

    IF button_area.contains(mouse_x, mouse_y):
        # Highlight the button when the mouse is over it
        highlight_button()


        # Toggle the menu when the button is clicked
        IF click:
            SET self.draw_menu TO not self.draw_menu

    ELSE:
        # Unhighlight the button when the mouse is not over it
        unhighlight_button()


    IF self.draw_menu:
        # Check IF the mouse is over any of the menu options

        FOR option IN menu_options:

            IF option_area.contains(mouse_x, mouse_y):
                # Highlight the option when the mouse is over it
                highlight_option()

                # Select the option when it is clicked
                IF click:
                    SET self.draw_menu TO False
                    SET self.active_option TO option
                    RETURN self.active_option

            ELSE:
                # Unhighlight the option when the mouse is not over it
                unhighlight_option()

    ELSE:
        # Reset the active option when the menu is closed
        SET self.active_option TO None
```

Explanation

When the function is called, it first checks whether the mouse cursor is within the bounds of the button_area. If it is, the button is highlighted to provide visual feedback to the user. If the button is clicked, the "draw_menu" attribute is toggled to either display or hide the menu. If the mouse cursor is not within the button_area, the button is unhighlighted.

If the "draw_menu" attribute is True, the function checks whether the mouse cursor is within any of the menu_options areas. If it is, the corresponding menu option is highlighted. If the menu option is clicked, the "draw_menu" attribute is set to False, and the "active_option" attribute is set to the corresponding option object. Finally, the active_option object is returned.

If the mouse cursor is not within any of the menu_options areas, the menu options are unhighlighted. If "draw_menu" is False, the "active_option" attribute is reset to None.

Overall, the function provides an interactive menu interface item that allows the user to select options using the cursor.

Parameters Dictionary:

Parameter(s)	Description
mouse_x: int	The x-coordinate of the mouse pointer.
mouse_y: int	The y-coordinate of the mouse pointer.
click: bool	A boolean value indicating whether the mouse is clicked or not.
button_area: object	An object representing the area occupied by the button.
menu_options: list	A list containing the menu options.
option_area: object	An object representing the area occupied by the menu options.
self.draw_menu: bool	A boolean indicating whether the menu should be drawn or not.
self.active_option: object	The currently selected menu option, if any.
highlight_button(): method	A method that highlights the button when the mouse is over it.
unhighlight_button(): method	A method that unhighlights the button when the mouse is not over it.
highlight_option(): method	A method that highlights a menu option when the mouse is over it.
unhighlight_option(): method	A method that unhighlights a menu option when the mouse is not over it.

Implementation:

Button

```
class Button():
    def __init__(self, font, text, width, height, pos, color, hover):
        self.original_y_pos = pos[1]
        self.color = color
        self.hover = hover
        self.clicked = False
        self.top_rect = pygame.Rect(pos,(width,height))
        self.top_color = color
        self.bottom_rect = pygame.Rect(pos,(width,height))
        font = font
        self.text_surf = font.render(text,True,'#FFFFFF')
        self.text_rect = self.text_surf.get_rect(center = self.top_rect.center)

    def draw_button(self, screen):
        action = False
        pos = pygame.mouse.get_pos()
        top_rect = self.top_rect.copy()

        if top_rect.collidepoint(pos):
            self.top_color = self.color
            if pygame.mouse.get_pressed()[0]:
                self.clicked = True

            elif pygame.mouse.get_pressed()[0] == 0 and self.clicked == True:
                self.clicked = False
                action = True
            self.top_color = self.hover
        else:
            self.top_color = self.color

        top_surf = pygame.Surface(top_rect.size, pygame.SRCALPHA)
        pygame.draw.rect(top_surf, self.top_color, (0, 0, *top_rect.size))
        screen.blit(top_surf, top_rect.topleft)

        screen.blit(self.text_surf, self.text_rect)
        return action
```

Button

```
mazeButton = Button(font, "Maze", 120, 40, (255, 4),
INACTIVE_BUTTON, ACTIVE_BUTTON)

runButton = Button(font, "Visualise", 120, 40, (380, 4),
INACTIVE_BUTTON, ACTIVE_BUTTON)

clearButton = Button(font, "Clear", 120, 40, (505, 4),
INACTIVE_BUTTON, ACTIVE_BUTTON)
```

Cell

This class creates a **Cell** object to represent a single cell in a grid.

Each cell has **properties** such as its coordinates, whether it is a starting or target point, whether it is a wall or blank space, and whether it has been visited.

The **goal** of the class is to handle cells in a bigger structure, such as a grid, and to allow for setting properties and retrieving neighboring cells.

The goal is **achieved** by creating Cell objects with their own properties, adding them to the structure, and manipulating them with the provided class methods.

The **draw** method draws the cell according to its position and size(settings). It also subtracts one pixel off the cell's edges so each cell has a space between each other.

The **set_neighbours** method of the Cell class sets the neighboring cells of that particular cell based on its position in the grid.

It determines the neighbors by **checking** the cells directly above, below, to the left, and to the right of the current cell.

```
CLASS Cell
    FUNCTION initialize(i, j)
        x,y <- i,j
        start <- False
        wall <- False
        target <- False
        blank <- True
        waiting <- False
        visited <- False
        prior <- None
        neighbours <- []
        distance <- Infinity
        menue <- False
        f, g, h <- 0,0,0

    FUNCTION draw(colour)
        draw.rect(colour, (x * cell_width, y * cell_height, cell_width -1,
cell_height -1))

    FUNCTION set_neighbours(grid)
        IF y < rows -1:
            neighbours.append(grid[x][y+1]) #up
        IF x < columns -1:
            neighbours.append(grid[x+1][y]) #right
        IF y > 0:
            neighbours.append(grid[x][y-1]) #down
        IF x > 0:
            neighbours.append(grid[x-1][y]) #left
```

Parameters Dictionary:

Input	Description
i, j	Coordinates of the cell in the grid.
x, y	Coordinates of the cell in the window.
start	Boolean indicating whether the cell is the starting cell.
wall	Boolean indicating whether the cell is a wall.
target	Boolean indicating whether the cell is the target cell.
blank	Boolean indicating whether the cell is blank (not a wall, start, or target cell).
waiting	Boolean indicating whether the cell is waiting to be visited by the search algorithm.
visited	Boolean indicating whether the cell has been visited by the search algorithm.
prior	Reference to the previous cell in the path.
neighbours	List of references to the neighboring cells.
distance	Distance from the starting cell to the current cell.
menue	Boolean indicating whether the cell is part of the menu.
f, g, h	Variables used in A* algorithm to calculate the cost of a cell.
Output	**Description**
draw(colour)	Draws the cell with the specified colour in the window.
set_neighbours(grid)	Sets the list of neighboring cells for the current cell based on the provided grid.
initialize(i, j)	Initializes a new Cell object with the provided coordinates and default attribute values.

Implementation:

Cell

```
class Cell:
    def __init__(self, i, j):
        self.x = i
        self.y = j
        self.start = False
        self.wall = False
        self.target = False
        self.blank = True
        self.waiting = False
        self.visited = False
        self.prior = None
        self.neighbours = []
        self.distance = float('inf')
        self.menue = False
        self.f, self.g, self.h = 0,0,0

    #for heapfunction to operate
    def __gt__(self, other):
        pass

    def make_start(self):
        self.start = True
        self.blank = False
        self.wall = False
        return self.start

    def make_target(self):
        self.target = True
        self.blank = False
        self.wall = False
        return self.target

    def make_wall(self):
        self.wall = True
        self.blank = False

    def make_blank(self):
        self.blank = True

    def remove_start(self):
        self.start = False
        return self.start

    def remove_target(self):
        self.target = False
        return self.target

    def remove_wall(self):
        self.wall = False
        self.blank = True

    def draw(self, win, colour):
        pygame.draw.rect(win, colour, (self.x * cell_width, self.y *
cell_height, cell_width -1, cell_height -1))

    def set_neighbours(self, grid):
        if self.y < rows -1:
            self.neighbours.append(grid[self.x][self.y+1]) #up
        if self.x < columns -1:
            self.neighbours.append(grid[self.x+1][self.y]) #right
        if self.y > 0:
            self.neighbours.append(grid[self.x][self.y-1]) #down
        if self.x > 0:
            self.neighbours.append(grid[self.x-1][self.y]) #left
```

FUNCTIONS

MakeGrid:

The **make_grid**() function creates a grid of Cell objects that is represented as a list of lists. Each inner list represents a row of cells, and each cell has a unique (i, j) coordinate.

To create the grid, the function iterates over the range of columns and rows, creates a new Cell object for each position in the grid, and appends it to a list that represents a row of cells. This row of cells is then appended to the grid list, representing the entire two-dimensional grid.

After constructing the grid, the set_neighbours() function is called to set the neighbors of each cell, and the grid is returned from the function.

```
FUNCTION make_grid()

    grid <- []

    FOR i <- 0 To columns
        arr <- []
        FOR j <- 0 To rows
            arr.append(Cell(i,j))
        grid.append(arr)

    set_neighbours(grid)

    RETURN grid
```

SetNeighbours:

The **set_neighbours**() function sets the neighbors of each cell in the grid. It does this by iterating through each cell in the grid and calling the set_neighbours method of that cell.

The set_neighbours method is explained in the CELL section

```
FUNCTION set_neighbours(grid)

    FOR i <- 0 To columns

        FOR j <- 0 To rows

            grid[i][j].set_neighbours(grid)
```

Implementations:

Grid

```python
#Create grid
def make_grid():
    grid = []
    for i in range(columns):
        arr = []
        for j in range(rows):
            arr.append(Cell(i,j))
        grid.append(arr)

    set_neighbours(grid)
    return grid
```

Neighbours

```python
#Set Neighbours
def set_neighbours(grid):
    for i in range(columns):
        for j in range(rows):
            grid[i]
[j].set_neighbours(grid)
```

MousePos:

The **get_mouse_pos**() retrieves the current position of the mouse cursor within the Pygame window. The x and y coordinates of the mouse cursor are extracted from the tuple returned by the **pygame.mouse.get_pos**() function and returned as separate variables.

It is used for users to interact with cells and/or clicking buttons.

```
FUNCTION get_mouse_pos()
    x <- pygame.mouse.get_pos()[0]
    y <- pygame.mouse.get_pos()[1]
    RETURN x,y
```

Heuristics:

The **heuristics**() function calculates the Manhattan distance (also known as L1 distance) which estimates the distance between two cells a and b, to prioritize which cells to explore first. It is the sum of the absolute differences of their respective x and y coordinates.

```
FUNCTION heuristics(a, b)
    RETURN sqrt((a.x - b.x)^2 + abs(a.y - b.y)^2)
```

Error MSG:

The **error_msg**() function displays a message box when a search algorithm fails to find a solution, and updates a boolean value to reflect the status of the search.

```
FUNCTION error_msg(searching)
    IF searching THEN
        messagebox("No Solution", "There is no solution")
        searching <- False
    RETURN searching
```

Implementations:

Heuristic

```python
#manhattan distance
def heuristics(a, b):
    return math.sqrt((a.x - b.x)**2 + abs(a.y - b.y)**2)
```

Mouse

```python
def get_mouse_pos():
    x = pygame.mouse.get_pos()[0]
    y = pygame.mouse.get_pos()[1]
    return x,y
```

Error

```python
def error_msg(searching):
    if searching:
        Tk().wm_withdraw()
        messagebox.showinfo("No Solution", "There is no solution")
        searching = False
    return searching
```

CreatePath Psuedocode:

The **create_path**() function creates a path from the end cell which is current to the start cell by backtracking through the prior property of each cell.

It takes **three arguments** - the start cell, an empty list to hold the path, and the current cell - and iteratively adds the prior property of each cell to the path list, starting from the current cell and moving backwards towards the start cell.

```
FUNCTION create_path(start, path, current)

    WHILE current.prior !<- start DO

        path.append(current.prior)

        SET current TO current.prior
```

DrawGrid :

The **draw_grid**() function displays the grid of cells in the window and colors each cell based on its current state. It iterates through each cell in the grid and checks its state to draw it with the appropriate color using the Cell draw() function.

This function also **sets** the menu and wall attributes of the first three rows of cells of the grid to True, indicating that they cannot be traversed. It is where the buttons are placed.

This helps in **visualizing** the grid's state and pathfinding algorithms that work on it.

```
FOR k IN range(len(grid)):
    FOR l IN range(0, 3):
        cell <- grid[k][l]
        cell.menue <- True
        cell.wall <- True

FOR i IN range(columns):
    FOR j IN range(rows):
        cell <- grid[i][j]
        IF cell is blank:
            draw cell as blank cell
        IF cell is waiting:
            draw cell as waiting cell
        IF cell has been visited:
            draw cell as visited cell
        IF cell is in the path:
            draw cell as path cell
        IF cell is a wall:
            draw cell as wall cell
        IF cell is the start cell:
            draw cell as start cell
        IF cell is the target cell:
            draw cell as target cell
```

Implementations:

Backtracking

```python
def create_path(start_cell, path, current_cell):
    while current_cell.prior != start_cell:
        path.append(current_cell.prior)
        current_cell = current_cell.prior
```

Draw Grid

```python
def draw_grid(grid, path):
    #set menue
    for k in range(len(grid)):
        for l in range(0,3):
            (grid[k][l]).menue = True
            (grid[k][l]).wall = True

    for i in range(columns):
        for j in range(rows):
            cell = grid[i][j]
            if cell.blank:
                cell.draw(window,BLANK)
            if cell.waiting:
                cell.draw(window, WAITING)
            if cell.visited:
                cell.draw(window, VISITED)
            if cell in path:
                cell.draw(window, PATH)
            if cell.wall:
                cell.draw(window, WALL)
            if cell.start:
                cell.draw(window, START)
            if cell.target:
                cell.draw(window, END)
```

USER INTERFACE

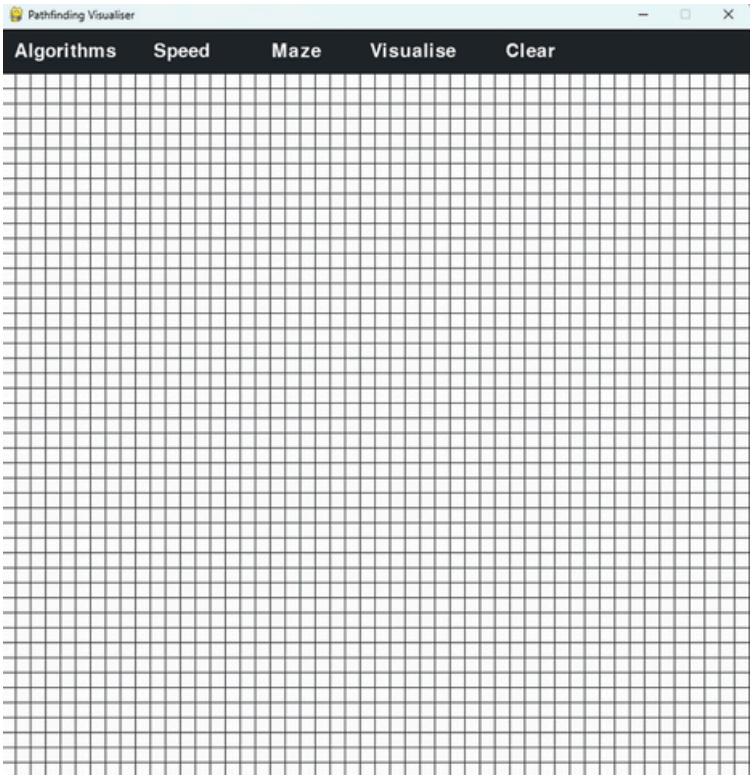
This current user interface design may be subject to potential modifications, although it has already undergone changes to adopt a more minimalistic approach, as seen in many modern apps and programs. The primary objective remains to maintain consistency throughout the program to ensure a seamless user experience. This approach strives to make it as easy as possible for the user to navigate the interface.

The user interface is divided into 2 drop down menues and 3 buttons. The main section is the grid section, which contains the 2D grid where the pathfinding algorithms are visualized. The grid section also contains three buttons: "Clear", "Maze", and "Visualize". The "Clear" button resets the entire grid to its initial state, the "Maze" button generates recursively a random maze on the grid, and the "Visualize" button starts the visualization of the pathfinding algorithm on the grid.

The first dropdown menue is the algorithm selection section, which allows users to choose from different pathfinding algorithms, including A*, Dijkstra's algorithm, Breadth-First Search (BFS), and Depth-First Search (DFS).

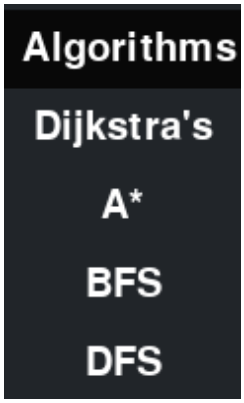
The second dropdown menue is the speed selection section, which allows users to choose the speed at which the pathfinding algorithm is visualized. Users can choose from two different speeds: slow and fast. Fast is automatically set as default if not changed.

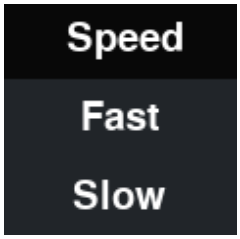
Overall, the user interface of the program is intuitive and easy to use, with clear and simple controls for selecting algorithms, speeds, and generating mazes. The visualization of the pathfinding algorithm on the grid is also very clear and easy to understand, making it a great tool for learning and experimenting with different pathfinding algorithms.



The grid it self is represented by colours shown in the settings section and a small gap is placed between the cells so that they can be differentiated easily

Below is an example of what the drop down buttons look like





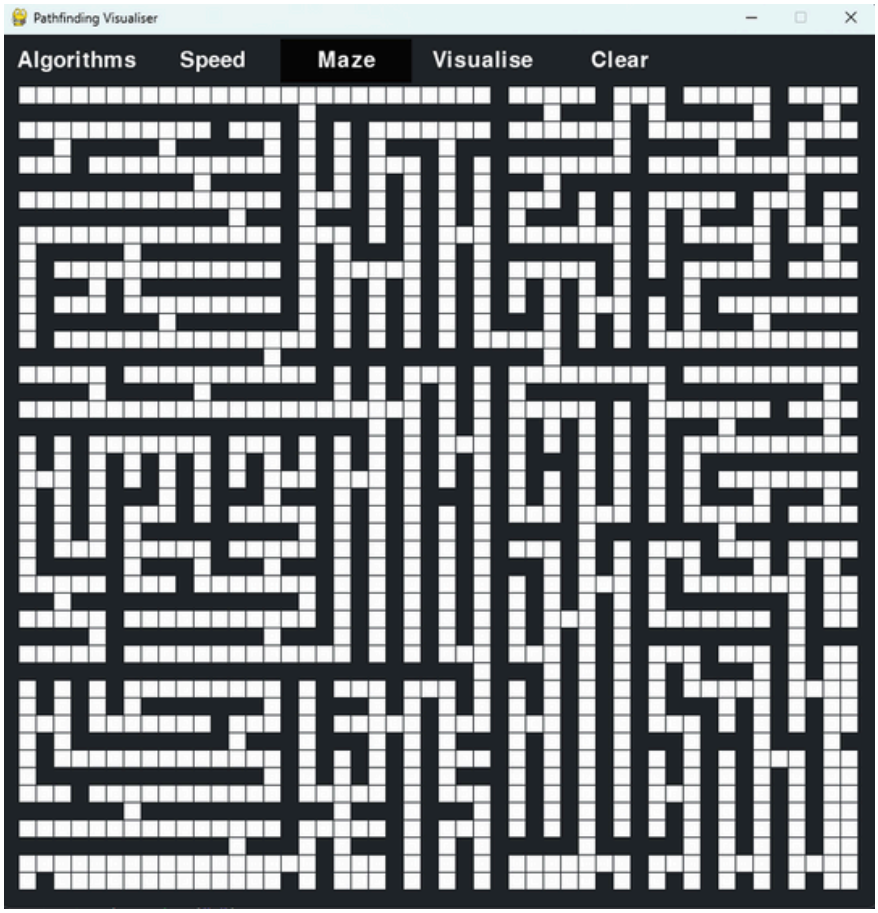
When the maze is drawn on the grid, it appears as a series of walls that block movement between cells. Each cell that is part of the maze is represented by a wall or empty space. The walls are dark coloured and the empty cells are white.

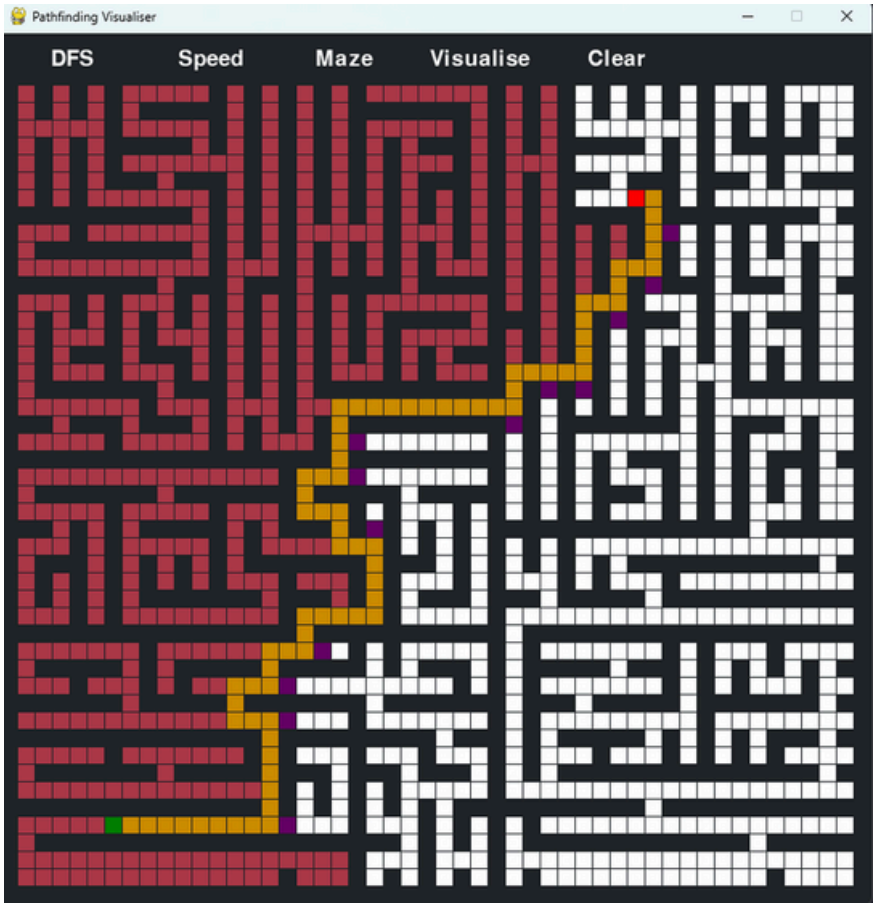
The start and end cells are represented by the colours green and red respectively on the grid. The start cell is the cell where the pathfinding algorithm will begin, and the end cell is the destination that the algorithm is trying to reach.

The path that the algorithm finds is represented by a yellow colour. Visited cells are a redish pink colour, and the neighbour cells within their appropriate data structure are coloured purple.

With a visually appealing and easy-to-use UI, users are more likely to engage with the application and use it more frequently.

And can improve the overall user experience, making it more enjoyable and intuitive for users to navigate the program.





MAZE

Here's how it works in simple terms:

- The maze starts as a full grid of empty spaces.
- The function takes in a maze object and four integer values that specify the bounds of the sub-grid being divided.
- The function checks whether the sub-grid is too small to be divided further, and if so, it returns and does nothing.
- If the sub-grid is large enough to be divided, the function randomly decides whether to divide it horizontally or vertically.
- If it decides to divide horizontally, it selects a random wallY value and sets walls in the sub-grid at positions (x, wallY) for all x values between startX and endX.
- After setting the walls, the function makes two recursive calls for the top and bottom sub-grids with updated values for the wallY parameter.
- If it decides to divide vertically, it selects a random wallX value and sets walls in the sub-grid at positions (wallX, y) for all y values between startY and endY.
- After setting the walls, the function makes two recursive calls for the left and right sub-grids with updated values for the wallX parameter.
- The process continues until all sub-grids are too small to be divided further, and the maze is complete.

```
function generateMazeRecursiveDivision(maze, startX, startY, endX, endY):

    if endX - startX < 2 or endY - startY < 2:
        return  # Base case: the maze is too small to divide further

    # randomly decide whether to divide horizontally or vertically
    horizontal = randomBoolean()

    if horizontal:
        wallY = randomInt(startY + 1, endY - 1)
        holeX = randomInt(startX, endX)  # choose a random hole in the wall
        for x in range(startX, endX + 1):
            if x != holeX and x != holeX + 1:  # leave a gap in the wall
                maze.setWall(x, wallY)

        # recursive call for top half
        generateMazeRecursiveDivision(maze, startX, startY, endX, wallY - 1)
        # recursive call for bottom half
        generateMazeRecursiveDivision(maze, startX, wallY + 1, endX, endY)

    else:
        wallX = randomInt(startX + 1, endX - 1)
        holeY = randomInt(startY, endY)  # choose a random hole in the wall

        for y in range(startY, endY + 1):
            if y != holeY and y != holeY + 1:  # leave a gap in the wall
                maze.setWall(wallX, y)

        # recursive call for left half
        generateMazeRecursiveDivision(maze, startX, startY, wallX - 1, endY)
        # recursive call for right half
        generateMazeRecursiveDivision(maze, wallX + 1, startY, endX, endY)
```

Explanation

The idea is to start with a full grid of empty spaces, and then recursively divide the grid into smaller sub-grids by adding walls. This process continues until the sub-grids are small enough that they cannot be further divided.

The function takes as input a maze object, which is a data structure that represents the maze. It also takes four integer values: startX, startY, endX, and endY, which specify the bounds of the sub-grid that is being divided.

The first thing the function does is check whether the sub-grid is too small to be divided further. If this is the case, the function simply returns and does nothing.

If the sub-grid is large enough to be divided, the function randomly decides whether to divide it horizontally or vertically. It does this by generating a random boolean value and storing it in the horizontal variable.

If horizontal is true, the function selects a random wallY value between startY and endY. It then iterates over each x value between startX and endX, and for each value, it sets the wall at position (x, wallY) in the maze.

After setting the walls, the function makes two recursive calls. The first recursive call is for the top half of the sub-grid, and it passes the same values for startX, startY, endX, and wallY - 1. The second recursive call is for the bottom half of the sub-grid, and it passes the same values for startX, wallY + 1, endX, and endY.

If horizontal is false, the function selects a random wallX value between startX and endX. It then iterates over each y value between startY and endY, and for each value, it sets the wall at position (wallX, y) in the maze.

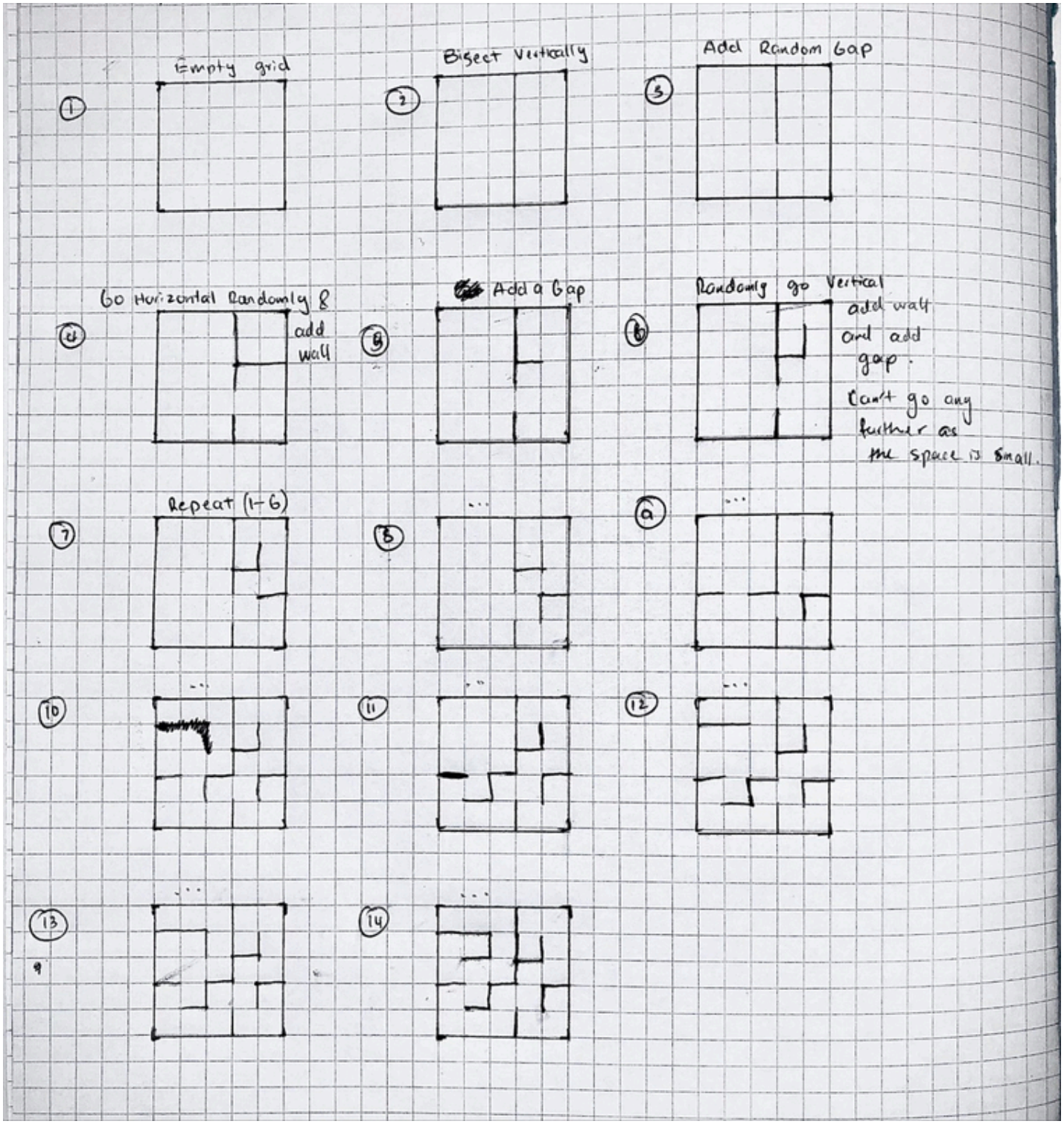
After setting the walls, the function makes two recursive calls. The first recursive call is for the left half of the sub-grid, and it passes the same values for startX, startY, wallX - 1, and endY. The second recursive call is for the right half of the sub-grid, and it passes the same values for wallX + 1, startY, endX, and endY.

At each recursive call, the function divides the sub-grid into two smaller sub-grids by adding walls. This process continues until all sub-grids are too small to be divided further, at which point the maze is complete

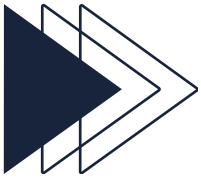
Input	Description
maze	A maze object that represents the maze being generated
startX, startY	Integers that specify the starting coordinates of the sub-grid being divided
endX, endY	Integers that specify the ending coordinates of the sub-grid being divided
Output	**Description**
None	The function modifies the maze object in place to generate a maze
Method	**Description**
randomBoolean()	Returns a random boolean value
randomInt(start, end)	Returns a random integer between start (inclusive) and end (inclusive)
maze.setWall(x, y)	Sets the wall at position (x, y) in the maze object

EXAMPLE WALKTHROUGH

1. Begin with an empty field.
2. Bisect the field with a wall, either horizontally or vertically. Add a single passage through the wall.
3. Repeat step #2 with the areas on either side of the wall.
4. Continue, recursively, until the maze reaches the desired resolution.



Implementation:



Maze

```
def maze(grid):
    #Fill in the outside walls, the space behind the menue will be
empty and wont be searched
    create_outside_walls(grid)

    #Start the recursive process
    make_maze_recursive_call(grid, columns - 1, 0, 2, rows - 1)

def create_outside_walls(grid):
    #Create left and right walls
    for i in range(len(grid)):
        (grid[i][2]).wall = True
        (grid[i][len(grid[i])-1]).wall = True

    #Create top and bottom walls
    for j in range(1, len(grid[0]) - 1):
        (grid[0][j]).wall = True
        (grid[len(grid) - 1][j]).wall = True

def make_maze_recursive_call(grid, top, bottom, left, right):
    #where to divide horizontally
    start_range = bottom + 2
    end_range = top - 1
    y = random.randrange(start_range, end_range, 2)

    #division
    for j in range(left + 1, right):
        (grid[y][j]).wall = True

    #where to divide vertically
    start_range = left + 2
    end_range = right - 1
    x = random.randrange(start_range, end_range, 2)

     #division
    for i in range(bottom + 1, top):
        (grid[i][x]).wall = True

     #make a gap on 3 of the 4 walls and which wall does NOT get a
gap
    wall = random.randrange(4)
    if wall != 0:
        gap = random.randrange(left + 1, x, 2)
        (grid[y][gap]).blank = True
        (grid[y][gap]).wall = False

    if wall != 1:
        gap = random.randrange(x + 1, right, 2)
        (grid[y][gap]).blank = True
        (grid[y][gap]).wall = False

    if wall != 2:
        gap = random.randrange(bottom + 1, y, 2)
        (grid[gap][x]).blank = True
        (grid[gap][x]).wall = False

    if wall != 3:
        gap = random.randrange(y + 1, top, 2)
        (grid[gap][x]).blank = True
        (grid[gap][x]).wall = False

     #if there's enough space, do a recursive call
    if top > y + 3 and x > left + 3:
        make_maze_recursive_call(grid, top, y, left, x)

    if top > y + 3 and x + 3 < right:
        make_maze_recursive_call(grid, top, y, x, right)

    if bottom + 3 < y and x + 3 < right:
        make_maze_recursive_call(grid, y, bottom, x, right)

    if bottom + 3 < y and x > left + 3:
        make_maze_recursive_call(grid, y, bottom, left, x)
```

DIJKSTRA'S

The **dijkstra**() function takes in the start and target cells, the current searching state, the priority queue, and the current path. It first checks if the queue is not empty and the search is still ongoing. If so, it removes the cell with the smallest distance from the queue and marks it as visited. If the current cell is the target cell, the search is completed and the function calls the **create_path**() function to trace the path from the start cell to the target cell.

The algorithm uses a **priority queue** to keep track of the cells to be visited and their distances from the start cell.

If the current cell being processed is not the target cell, the algorithm iterates through its neighboring cells and calculates their distances from the start cell. Initially, all tentative distances are set to infinity within the Cell class except for the start cell, which has a distance of zero. The current distance is the total distance travelled from the start cell, which is incremented by one as each neighboring cell is processed.

If the new distance of a neighboring cell is less than the current distance, the neighbours distance is updated and the cell is marked as "waiting". This attribute refers to cells that have been processed but not yet visited. It helps to differentiate these cells from others and assign different colors to them. This makes it easier to keep track of which cells need further processing and improves data clarity.

The neighboring cell is then inserted into a priority queue to be arranged in shortest distance from the start cell. The current cell is set as the prior cell of its shortest distance neighbor, which creates a chain of prior cells forming the cheapest path to the current neighboring cell.

The function **continues** this process until either the target cell is found or the queue is empty. If the target cell is not found, the error_msg() function is called to display an error message.

The **searching flag** is used to keep track of whether the algorithm is still searching for the target cell. The function returns the updated value of the searching flag.

```
FUNCTION dijkstra(start_cell, target_cell, searching, pq, path)

    IF pq.size() > 0 and searching

        current_distance, current_cell TO pq.remove()
        current_cell.visited TO True

        IF current_cell <- target_cell
            searching TO False
            create_path(start_cell, path, current_cell)

        ELSE:
            FOR neighbour IN current_cell.neighbours:

                IF not neighbour.waiting and not neighbour.wall
                    distance TO current_distance + 1

                    IF distance < neighbour.distance
                        neighbour.distance TO distance
                        neighbour.waiting TO True
                        pq.insert(distance, neighbour)
                        neighbour.prior TO current_cell
    ELSE:
        searching TO error_msg(searching)

    RETURN searching
```

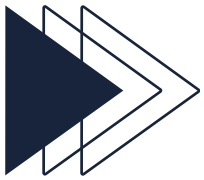
Here's how it works in simple terms:

- Check if there are still cells in the priority queue to explore and if the search is ongoing.
- Remove the cell with the smallest distance from the priority queue and mark it as visited.
- If the current cell is the target cell, the search is successful. Create the path from the start cell to the target cell and set the searching variable to false.
- If the current cell is not the target cell, loop through its neighbors.
- If the neighbor cell has not been explored and it's not a wall, calculate the distance to it from the start cell.
- If the new distance is smaller than the previous distance to the neighbor cell, update its distance, mark it as waiting, set its priority to the current cell, and add it to the priority queue.
- If there are no more cells to explore in the priority queue, set searching to an error message.
- Return the searching variable.

Parameters Dictionary:

Input	Description
start_cell	The starting cell for the search algorithm
target_cell	The target cell for the search algorithm
searching	A boolean indicating if the search is still ongoing
pq	A priority queue containing cells to be explored
path	An empty list to store the path from start_cell to target_cell
Output	**Description**
searching	A boolean indicating if the search is still ongoing or encountered an error

Implementation:



Dijkstra's

```
def dijkstra(start_cell, target_cell, searching, pq, path):
    #when the queue is not empty
    if pq.size() > 0 and searching:
        current_distance, current_cell = pq.remove()
        current_cell.visited = True

        if current_cell == target_cell:
            searching = False
            # traces its prior cells that it neigboured
            create_path(start_cell, path, current_cell)

        else:
            for neighbour in current_cell.neighbours:

                if not neighbour.waiting and not neighbour.wall:
                    distance = current_distance + 1

                    #change the distance of each cell when
searching to find the shortest path
                    if distance < neighbour.distance:
                        neighbour.distance = distance
                        neighbour.waiting = True
                        pq.insert(distance, neighbour)
                        neighbour.prior = current_cell
    else:
        searching = error_msg(searching)

    return searching
```

BFS

The **BFS** algorithm uses a queue data structure to store and visit cells in the grid in a level-by-level order.

The **bfs**() function takes in the starting cell, target cell, the searching flag, a queue data structure, the current path, and executes the BFS algorithm on the grid.

The function **removes** a cell from the queue and marks it as visited, checks if it is the target cell and creates a path if it is. If the current cell is not the target cell, the function checks its neighboring cells and adds them to the queue if they have not been visited, are not walls, and sets their waiting attribute to True. The current cell is set as the prior cell of its shortest distance neighbour which forms a chain of prior cells forming the shortest path to the current neighbour.

The function **continues** this process until either the target cell is found or the queue is empty. If the target cell is not found, the error_msg() function is called to display an error message.

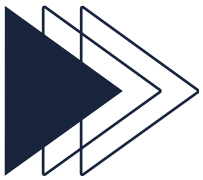
The **searching flag** is used to keep track of whether the algorithm is still searching for the target cell. The function returns the updated value of the searching flag.

```
FUNCTION bfs(start_cell, target_cell, searching, queue, path)

    IF queue.size() > 0 and searching
        current_cell <- queue.dequeue()
        current_cell.visited <- True

        IF current_cell EQUALS target_cell

            searching <- False
            create_path(start_cell, path, current_cell)

        ELSE
            FOR neighbour IN current_cell.neighbours

                IF not neighbour.waiting and not neighbour.wall

                    neighbour.waiting <- True

                    neighbour.prior <- current_cell

                    queue.enqueue(neighbour)
    ELSE

        searching <- error_msg(searching)

    RETURN searching
```

Parameters Dictionary:

Input	Description
start_cell	The starting cell of the search algorithm
target_cell	The target cell that the algorithm is trying to reach
searching	A boolean variable indicating whether the algorithm is still searching for the target cell or not
queue	The queue data structure used to hold cells to be visited next in the algorithm
path	The list of cells representing the path found by the algorithm
Output	**Description**
searching	A boolean variable indicating whether the algorithm has found the target cell or not

Implementation:



BFS

```
def bfs(start_cell, target_cell, searching, queue, path):

    if queue.size() > 0 and searching:
        current_cell = queue.dequeue()
        current_cell.visited = True

        if current_cell == target_cell:
            searching = False
            # traces its prior cells that it neigboured
            create_path(start_cell, path, current_cell)

        else:
            for neighbour in current_cell.neighbours:
                if not neighbour.waiting and not neighbour.wall:

                    neighbour.waiting = True
                    #stores the prior cell
                    neighbour.prior = current_cell
                    queue.enqueue(neighbour)
    else:
        searching = error_msg(searching)

    return searching
```

DFS

The dfs() function takes in the start cell, target cell, a searching flag, a stack, and a path.

The function pops a cell from the stack and marks it as visited, checks if it is the target cell and creates a path if it is. If the current cell is not the target cell, the function checks its neighbours and adds them to the stack if they have not been visited and are not walls, and sets their waiting attribute to True. The current cell is set as the prior cell of its shortest distance neighbour which forms a chain of prior cells forming the shortest path to the current neighbour.

The function **continues** this process until either the target cell is found or the queue is empty. If the target cell is not found, the error_msg() function is called to display an error message.

The **searching flag** is used to keep track of whether the algorithm is still searching for the target cell. The function returns the updated value of the searching flag.

```
FUNCTION dfs(start_cell, target_cell, searching, stack, path)
    IF stack.size() > 0 and searching
        current_cell <- stack.pop()
        current_cell.visited <- True
        IF current_cell EQUALS target_cell
            searching <- False
            create_path(start_cell, path, current_cell)
        ELSE
            FOR neighbour IN current_cell.neighbours
                IF not neighbour.visited and not neighbour.wall
                    neighbour.waiting <- True
                    neighbour.prior <- current_cell
                    stack.push(neighbour)
    ELSE
        searching <- error_msg(searching)
    RETURN searching
```

Here's how it works in simple terms:

- This is a function called dfs that implements depth-first search algorithm for pathfinding.
- The function takes inputs start_cell, target_cell, searching, stack, and path.
- It checks if stack has any cells left to visit and if searching is true.
- It pops the top cell from the stack and marks it as visited.
- If the popped cell is the target_cell, it sets searching to false and creates a path from start_cell to target_cell.
- Otherwise, it checks each of the neighboring cells of the popped cell.
- If a neighboring cell is not visited and is not a wall, it marks it as waiting and sets its prior value to the current cell. Then, it pushes the neighboring cell onto the stack.
- If the stack is empty or searching is false, the function returns an error message.
- The function returns the value of searching.

Parameters Dictionary:

Input	Description
start_cell	The starting cell of the pathfinding algorithm
target_cell	The target cell to reach through pathfinding
searching	A boolean variable representing whether the algorithm is searching or not
stack	A data structure that stores the cells to visit in the future
path	The list that will contain the final path
Output	**Description**
searching	A boolean variable representing whether the target cell was found or not

DFS Implementation:

DFS

```
def dfs(start_cell, target_cell, searching, stack, path):

    if stack.size() > 0 and searching:
        current_cell = stack.pop()
        current_cell.visited = True

        if current_cell == target_cell:
            searching = False
            # traces its prior cells that it neigboured
            create_path(start_cell, path, current_cell)

        else:
            for neighbour in current_cell.neighbours:
                if not neighbour.visited and not neighbour.wall:

                    neighbour.waiting = True
                     #stores the prior cell
                    neighbour.prior = current_cell
                    stack.push(neighbour)
    else:
        searching = error_msg(searching)

    return searching
```

A*

The A* algorithm is a pathfinding algorithm that uses a heuristic function to estimate the distance from the current cell to the target cell. The algorithm works by exploring each cell based on its total cost (f-score), which is the sum of its distance from the start cell (g-score) and an estimated distance to the target cell (h-score).

The function takes in the start cell, target cell, a boolean variable "searching", two sets of cells "openSet" and "closeSet", and a list "path" to store the shortest path.

The function first checks if the openSet is not empty and the "searching" variable is True. If it is, the function sets the "current_cell" to be the cell in the openSet with the lowest f-score. The function then marks the "current_cell" as visited, removes it from the openSet, and adds it to the closeSet.

If the "current_cell" is the same as the "target_cell", the function sets the "searching" variable to False and creates the shortest path using the "create_path" function.

If the "current_cell" is not the "target_cell", the function checks each of its neighbors. If a neighbor has not been visited before and is not a wall, the function calculates its tentative g-score (the distance from the start to the current cell plus the cost to move to that neighbor) and compares it to the current g-score of the neighbor. If the tentative g-score is lower than the current g-score, the function updates the neighbor's g-score, sets the neighbor as waiting, calculates its h-score (the estimated distance from the neighbor to the target), and sets its f-score to be the sum of its g-score and h-score. The function also sets the neighbor's prior cell to be the current cell.

Repeat until the target is found or the openSet is empty

If the openSet is empty or searching has ended due to an error, call the **error_msg** function, and return the updated searching flag at the end.

```
FUNCTION a_star(start_cell, target_cell, searching, openSet, closeSet, path)
    IF len(openSet) > 0 and searchin
        current_cell <- the cell in openSet with the lowest f-score
        current_cell.visited <- True
        openSet.remove(current_cell)
        closeSet.append(current_cell)

        IF current_cell EQUALS target_cell
            searching <- False
            create_path(start_cell, path, current_cell)
        ELSE
            FOR neighbour IN current_cell.neighbours
                IF not neighbour.visited and not neighbour.wall
                    tempG <- current_cell.g + 1
                    IF neighbour IN openSet
                        IF tempG < neighbour.g:
                            neighbour.g <- tempG
                    ELSE:
                        neighbour.g <- tempG
                        openSet.append(neighbour)
                        neighbour.waiting <- True
                    neighbour.h <- heuristics(neighbour, target_cell)
                    neighbour.f <- neighbour.g + neighbour.h
                    neighbour.prior <- current_cell
    ELSE
         searching <- error_msg(searching)
    RETURN searching
```

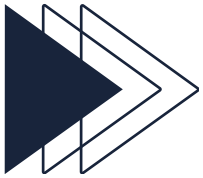
Here's how it works in simple terms:

- The function takes as input the start and target cells of the maze, a boolean variable called 'searching' to keep track of whether the search is still in progress, open and close sets to keep track of which cells have been visited and which are yet to be visited, and an empty list called 'path' to store the final solution path.
- The function checks if there are still cells in the open set and the search is still ongoing.
- It selects the cell with the lowest f-score from the open set and sets it as the current cell.
- The current cell is marked as visited and removed from the open set and added to the close set.
- If the current cell is the target cell, the search is complete, and the path is created by calling the create_path function from the start cell to the current cell.
- If the current cell is not the target cell, it evaluates each of its neighbors to determine which cells to visit next.
- For each neighbor that has not yet been visited and is not a wall, the function calculates the tentative G-score (the distance from the start cell to the neighbor cell), and updates the neighbor's score and other parameters as necessary.
- If the neighbor is already in the open set, its score is updated if the tentative G-score is lower than its current G-score. If the neighbor is not in the open set, it is added to the open set, and its scores are updated accordingly.
- The function then repeats the process by selecting the next cell with the lowest f-score from the open set, continuing the search until the target cell is found or the open set is empty.
- If the open set is empty and the search is still ongoing, the function returns an error message, indicating that there is no path to the target cell.
- The function returns the updated boolean variable 'searching'.

Parameters Dictionary:

Input	Description
start_cell	The starting cell for the pathfinding algorithm
target_cell	The target cell for the pathfinding algorithm
searching	A Boolean flag indicating if the algorithm is still running
openSet	A list of cells that are available for exploring
closeSet	A list of cells that have been explored
path	The path from start_cell to target_cell
Output	**Description**
searching	A Boolean flag indicating if the algorithm is still running

Implementation:



A*

```
def a_star(start_cell, target_cell, searching, openSet, closeSet, path):

    if len(openSet) > 0 and searching:
        winner = 0

        for i in range(len(openSet)):
            if openSet[i].f < openSet[winner].f:
                winner = i

        current_cell = openSet[winner]
        current_cell.visited = True
        openSet.remove(current_cell)
        closeSet.append(current_cell)

        if current_cell == target_cell:
            searching = False
            # traces its prior cells that it neigboured
            create_path(start_cell, path, current_cell)

        else:
            for neighbour in current_cell.neighbours:
                if not neighbour.visited and not neighbour.wall:
                    tempG = current_cell.g + 1

                    if neighbour in openSet:
                        if tempG < neighbour.g:
                            neighbour.g = tempG

                    else:
                        neighbour.g = tempG
                        openSet.append(neighbour)
                        neighbour.waiting = True

                    neighbour.h = heuristics(neighbour, target_cell)
                    neighbour.f = neighbour.g + neighbour.h
                    neighbour.prior = current_cell

    else:
         searching = error_msg(searching)

    return searching
```

PYGAME LIBRARY

Pygame is a Python library used for building video games and other multimedia applications. It provides various functions and modules that allow developers to create interactive games with 2D graphics and sounds. One of the key features of Pygame is its ability to create a game window.

The game window created by Pygame provides a graphical interface for the user to interact with the game. It can be customized in terms of its size, title, and background color. The window can be created using the pygame.display.set_mode() function, which takes in the size of the window as a tuple of the form (width, height).

Once the window is created, Pygame provides a Surface object that represents the window. The Surface object is used to display images, text, and other graphical elements on the window. It also provides functions for updating the contents of the window and handling user input.

In addition to creating the game window, Pygame also provides features for managing events, such as mouse clicks and keyboard presses, and for handling graphics and sound. I will use these features to facilitate the creation of the visualiser.

Pygame also offers a range of drawing functions that can be used to design various UI elements such as text, images, and buttons. These functions are a great starting point for creating basic UI elements. However, in some cases, these features may be limited in terms of customization and functionality.

That said, with a bit of creativity and programming skills, I may be able to take Pygame's capabilities to the next level by creating more complex UI elements. For instance, I can usePygame to design dropdown buttons and normal buttons that possess active and inactive functionalities. These additional features will make the UI elements more sophisticated and user-friendly, improving the overall user experience.

MAIN LOOP

At the beginning of the code,**clear**() resets all variables used in the program to their default values, to ensure that all variables are initialized to their default values.

The program then sets searching to False, creates a 2D grid using the **make_grid**() function, and initializes two empty strings called selected_algorithm and selected_speed.

The **main loop** then enters an infinite loop that handles user input and updates the display. The first part of the loop checks for events in the event queue using pygame.event.get(). If the user clicks the "Quit" button, the program quits.

If the **begin_search** variable is False, the program checks if the left mouse button is pressed. If it is, the program gets the current mouse position using get_mouse_pos(), calculates the grid cell that the mouse is over, and sets the corresponding cell in the grid to be the start cell, target cell, or wall, depending on the current state of the program. Conditions are set so that if the start, target and walls are placed respectively. If either the start and target are removed they will be continually placed next in order of priority

If the **right** mouse **button** is pressed, the program removes the cell that the mouse is over from the grid.

Main

```
def main():
    #resets the variables
    def clear():
        begin_search = False
        start_cell_set = False
        target_cell_set = False
        start_cell = None
        target_cell = None
        maze_set = False
        path = []
        return begin_search, start_cell_set, target_cell_set,
start_cell, target_cell, maze_set, path

    begin_search, start_cell_set, target_cell_set, start_cell,
target_cell, maze_set, path = clear()
    searching = False
    grid = make_grid()
    selected_algorithm, selected_speed = "", ""

    while True:
        #FPS
        fpsClock.tick(200)

        event_list = pygame.event.get()

        #event handler
        for event in event_list:
            if event.type == pygame.QUIT:
                # Quit window
                pygame.quit()
                sys.exit()

            if not begin_search:
                if pygame.mouse.get_pressed()[0]:
                    # Set nodes
                    x, y = get_mouse_pos()
                    i = x // cell_width
                    j = y // cell_height
                    cell = grid[i][j]

                    if cell.menue:
                        pass
                    elif not start_cell_set:
                        # Set start
                        start_cell = cell
                        start_cell_set = cell.make_start()
                    elif not target_cell_set and not cell.start:
                        # Set target
                        target_cell = cell
                        target_cell_set = cell.make_target()
                    elif not cell.start and not cell.target:
                        # Set wall
                        cell.make_wall()

                elif pygame.mouse.get_pressed()[2]:
                    # Remove nodes
                    x, y = get_mouse_pos()
                    i = x // cell_width
                    j = y // cell_height
                    cell = grid[i][j]
                    cell.make_blank()

                    if cell.start:
                        # Remove start
                        start_cell_set = cell.remove_start()
                    elif cell.target:
                        # Remove target
                        target_cell_set = cell.remove_target()
                    else:
                        # Remove wall
                        cell.remove_wall()
```

The program **updates** the drop-down menus for the pathfinding algorithms and speeds, and updates corresponding variables if an option is selected.

If the "**begin_search**" variable is True, the program calls the selected pathfinding algorithm function (a_star(), dijkstra(), bfs(), or dfs()) with appropriate arguments. The search function updates variables used for visualizing the search.

The program sleeps for a short time if the "**Slow**" option is selected. Fast speed is set on default.

If the "**Maze**" button is clicked, a random maze is generated using the **maze()** function if one doesn't already exist.

If the "**Run**" button is clicked and both the start and target cells are set, the selected pathfinding algorithm is called to begin the **search** and the start cell is added to the data structures for processing.

If the "**Clear**" button is clicked, all variables are reset and a new grid is created using the **make_grid()** function.

The program then **draws** the grid, drop-down menus, and buttons using their respective functions and updates the display.

Main

```
# Updates drop down menu options for algorithms
selected_algo = algorithms.update(event_list)
if selected_algo >= 0:
    selected_algorithm = algorithms.options[selected_algo]
    algorithms.main = selected_algorithm

# Updates drop down menu options for speed
selected_speed_menue = speed_menue.update(event_list)
if selected_speed_menue >= 0:
    selected_speed = speed_menue.options[selected_speed_menue]
    speed_menue.main = selected_speed

# Check the selected algorithm and execute the corresponding search function
if begin_search:
    if selected_algorithm == "A*":
        searching = a_star(start_cell, target_cell, searching, openSet, closeSet, path)
    elif selected_algorithm == "Dijkstra's":
        searching = dijkstra(start_cell, target_cell, searching, pq, path)
    elif selected_algorithm == "BFS":
        searching = bfs(start_cell, target_cell, searching, queue, path)
    elif selected_algorithm == "DFS":
        searching = dfs(start_cell, target_cell, searching, stack, path)

    # Slow speed button
    if selected_speed == "Slow":
        time.sleep(0.2)
    # Fast speed button
    elif selected_speed == "Fast":
        pass

if mazeButton.clicked and not maze_set and not begin_search:
    maze(grid)
    maze_set = True

if runButton.clicked and target_cell_set and start_cell_set and not begin_search:
    begin_search = True
    searching = True
    start_cell.visited = True
    stack = Stack()
    stack.push(start_cell)
    openSet, closeSet = [], []
    openSet.append(start_cell)
    queue = Queue()
    queue.enqueue(start_cell)
    pq = PriorityQueue()
    pq.insert(0, start_cell)

if clearButton.clicked:
    begin_search, start_cell_set, target_cell_set, start_cell, target_cell, maze_set, path =
clear()
    grid = make_grid()

#draw functions
window.fill(INACTIVE_BUTTON)
draw_grid(grid,path)
algorithms.draw(window)
speed_menue.draw(window)
mazeButton.draw_button(window)
clearButton.draw_button(window)
runButton.draw_button(window)
pygame.display.flip()
```

TESTING

Intro

The purpose of this testing document is to ensure that the Pathfinding Visualizer performs optimally in all scenarios, accurately represents the algorithms it visualizes, and is free from any critical bugs or issues. Great care has been taken to develop and test the visualizer to the highest standards, and this document outlines the testing processes followed to ensure its quality and reliability.

It contains detailed instructions on how to test each feature of the visualizer. By following these instructions, I will be able to evaluate the visualizer's performance, identify any bugs or issues, and provide valuable feedback on how to improve the visualizer further.

I have provided evidence of thorough testing through carefully selected samples, demonstrating the robustness and completeness of the solution. This ensures that all or most of the requirements have been met.

TESTING CRITERIA

The performance of the project will be assessed to determine if it meets its description, and objectives.

Functionality Testing:

- Test the ability to set and remove the start points, end points and walls on the grid.
- Ensure that the visualiser works correctly for all supported algorithms.
- Verify that the visualiser generates a maze correctly and that all maze generation algorithms are functioning correctly.
- Confirm that the visualiser can correctly solve mazes and generate the shortest path from the start node to the end node.

Performance Testing:

- Verify that the visualiser runs smoothly and quickly without any lags or delays.
- Test the visualiser's performance when generating and solving large mazes.

User Interface Testing:

- Verify that the user interface is intuitive and easy to use.
- Test that the interface is responsive and visually appealing.
- Check that the user can easily change the start and end points and that the maze can be reset.
- Ensure that the buttons function correctly

Compatibility Testing:

- Test the visualiser on different hardwares and operating systems to ensure compatibility.

Edge Case Testing:

- Test the visualiser on mazes with extreme wall densities, start and end positions, and other edge cases.
- Verify that the visualiser can handle invalid inputs and user errors gracefully.
- Test the visualiser's behavior when it encounters errors or exceptions during maze generation or solving.

NOTE:
In order to demonstrate the robustness and thoroughness of testing, multiple sample cases will be run by user groups and myself for each test case, with different maze generations and obstacle placements. Test results will be recorded and compared to the expected outcomes.

Green: Pass Red:Fail

Test Case 1: Start and End Point

- Test the ability to set the start and end points on the grid.
- Input: Click on two cells on the grid to set them as start and end points.
- Expected Output: The start and end points are highlighted and saved as variables.

Test Case 2: Obstacle Placement

- Test the ability to place obstacles on the grid.
- Input: Click and drag the mouse to draw obstacles on the grid.
- Expected Output: Obstacles are drawn on the grid and cells are marked as unpassable.

Test Case 3: Dijkstras Algorithm

- Test the ability of the pathfinding algorithm to find a path from start to end.
- Expected Output: A path is displayed on the grid from start to end, if a path exists.

Test Case 4: A* Algorithm

- Test the ability of the pathfinding algorithm to find a path from start to end.
- Expected Output: A path is displayed on the grid from start to end, if a path exists.

Test Case 5: BFS Algorithm

- Test the ability of the pathfinding algorithm to find a path from start to end.
- Expected Output: A path is displayed on the grid from start to end, if a path exists.

Test Case 6: DFS Algorithm

- Test the ability of the pathfinding algorithm to find a path from start to end.
- Expected Output: A path is displayed on the grid from start to end, if a path exists.

Test Case 7: Reset the Grid

- Test the ability to reset the grid and start over.
- Input: Click the "clear" button.
- Expected Output: The grid is cleared of all obstacles and the start and end points are removed.
-

Test Case 8: Node Overriding

- Input: Try overiding start and end nodes with wall nodes.
- Expected Outcome: start and end nodes dont change unless removed.

Test case 9: Random maze generation

- Input: Click on the "Generate Maze" button.
- Expected output: Maze generation is always random.

Test case 10: Algorithm run time

- Input: Change the speed to slow.
- Expected output: Algorithm execution is slowed.

Test case 11: Algorithm run time during traversal

- Input: Change the speed when the algorithm is running.
- Expected output: Speed automatically changes the algorithm execution.

Test case 12: Change algorithm during traversal

- Input: Change the algorithm after the visualisation has already started.
- Expected output: Error message pops up, stating no path an be found.

Test case 13: Cell removal during traveral

- Input: Try removing walls and cells when running.
- Expected output: No cells should be removed.

Test case 14: Create Maze during traveral

- Input: Try pressing the maze button when running.
- Expected output: No maze should be created.

Test case 15: Exit button

- Input: Exit out of the program window.
- Expected output: The program should close

Test case 16: Outside of bounds

- Input: Try dragging walls outside of the program window.
- Expected output: Program should not crash no cells must be placed.

Test case 17: Generation Delay

- Input: Visualise the path from one corner to the opposite corner.
- Expected output: There should be no delay in how quick cells are visited.
- Fault: On lower end hardware the visualisation speed slows down a little when nighbours increase tremendously
- Solution: Remove the FPS cap, so that each idividual hardware can visualise freely.

Test Case 18: Path Unavailable

- Test the ability of the pathfinding algorithm to handle situations where a path does not exist.
- Input: Create obstacles that block the path from start to end, then click "find path" button.
- Expected Output: An error message is displayed, indicating that no path was found.

Test Case 19: Speed of Algorithm

- Test the speed of the pathfinding algorithm for large traversals.
- Input: Visualise from one corner of a maze to its opposite other corner.
- Expected Output: The algorithm finds a path within a reasonable amount of time.

Test Case 20: User Interface

- Test the user interface for ease of use and accessibility.
- Input: Interact with the user interface and complete various tasks.
- Expected Output: The UI has no errors is intuitive and easy to use.

Test Case 21: Project Description

- Test the visualiser by following the project description.
- Input: Interact with the user interface and complete the various tasks.
- Expected Output: Each description is met without any delays.

Test Case 22: Remove Cells

- Test start, target and wall cells reset function.
- Input: Right click on a non blank cell.
- Expected Output: The cells turn blank.

Here is a link and QR code to a time stamped video where I perform all the tests:

https://youtu.be/PuJ_aVPFzNs

OBJECTIVES COMPARISON

1. Buttons
    a. **Left Mouse Click on grid**
        i. Set current coordinates as a start cell
        ii. if start already placed set target cell
        iii. if start and target already placed set wall cell
    b. **Right Mouse Click on grid**
        i. Reset cell and make it blank
    c. **Pathfinding Algorithms**
        i. 1)Add the start cell to the visited set.
        ii. 2) Add all not-visited neighbors of that cell to the search set.
        iii. 3) If the search set is empty, or if the target is found we stop here and go to step e(path).
        iv. 4) Else we pick a cell from the search set and repeat(go back to step 1).
        v. Dijkstras
            a. Treat the search set as a priority queue or any data structure that is based on priority, and you pick based on accumulated weight.
            1. A*
                a. Treat the search set as a priority queue or any data structure that is based on priority, and pick based on accumulated weight + some heuristic.
            2. BFS
                a. Treat the search set as a queue and pick in First In First Out order.
            3. DFS
                a. Treat the search set as a stack and pick in Last In First Out order.
        vi. Path
            1. If Path found
                a. Visualise the path from the start cell to the target cell
            2. If no path found and search set is empty
                a. Give an error message stating "There is no path to the end goal".
    d. **Maze**
        i. Develop a recursive division algorithm that creates a rectangular grid with an outside wall and an entrance/exit.
        ii. Ensure that the algorithm can divide the grid into two sub-grids with a wall between them, either horizontally or vertically.
        iii. Randomly choose a point on the wall between the sub-grids to create an opening that connects the two sub-grids.
        iv. Implement a mechanism to repeat steps 3 and 4 for each sub-grid until the desired complexity is achieved.
        v. Validate the maze using an algorithm to ensure that it is solvable and that there is at least one path from the entrance to the exit.
        vi. Incorporate a visual representation of the maze to aid in navigation and user experience
    e. **Visualise**
        i. Begin the search
        ii. Send the start cell to selected algorithm
        iii. Send the target cell to the selected algorithm
    f. **Clear**
        i. Reset every cell to blank
        ii. Reset cell neighbours
        iii. Reset Variables
    g. **Speed**
        i. Fast
            1. Limit to algorithm performace.
        ii. Slow
            1. Sleep system to 0.2 of a second

Here are tables summarizing the pass/fail status of the objectives and the final outcome:

All of the objectives are aligned with the test cases, as demonstrated in the video. Through each test, I was able to verify and validate that the objectives have been achieved successfully. The testing cases were designed to evaluate different aspects of the objectives, ensuring that all requirements were met. The video showcases the results of each test and provides a clear demonstration of how the objectives were met.

1. Left Mouse Click on grid	Pass/Fail	How it passed
Left mouse click on grid sets current coordinates as start cell	Pass	Tested with multiple clicks on different cells and each time the start cell was set to the correct coordinates.
If start already placed, left mouse click sets target cell	Pass	Tested by placing a start cell and then clicking on a different cell. The new cell was correctly set as the target cell.
If start and target already placed, left mouse click sets wall cell	Pass	Tested by placing a start and target cell and then clicking on a different cell. The new cell was correctly set as a wall cell.

2. Right Mouse Click on grid	Pass/Fail	How it passed
Right mouse click on grid resets cell	Pass	The function was tested multiple times by right-clicking on various cells in the grid, and each time the clicked cell was successfully reset to a blank state.

All pathfinding algorithms passed by completing test case 3,4,5,6

3. Pathfinding Algorithms	Pass/Fail	How it passed
Add the start cell to the visited set.	Pass	Tested by starting the algorithm with a valid start cell and checking that it is added to the visited set.
Add all not-visited neighbors of that cell to the search set.	Pass	Tested by selecting a cell with neighbors that haven't been visited and checking that they are added to the search set.
If the search set is empty, or if the target is found we stop here and go to step e(path).	Pass	Tested by running the algorithm with a search set that becomes empty or reaching the target, and verifying that the algorithm stops.
Else we pick a cell from the search set and repeat(go back to step 1).	Pass	Tested by selecting a cell from the search set and repeating the algorithm from step 1.
Dijkstras	Pass	Tested by using a priority queue and selecting cells based on their accumulated weight. And running the algorithm.
A*	Pass	Tested by using a similar data structure to a priority queue and selecting cells based on their accumulated weight plus some heuristic. And running the algorithm.
BFS	Pass	Tested by using a queue and selecting cells in first in first out order. And running the algorithm.
DFS	Pass	Tested by using a stack and selecting cells in last in first out order. And running the algorithm.
Path found	Pass	Tested by running the algorithm and verifying that a path is found and visualized correctly.
No path found	Pass	Tested by running the algorithm with a target that is not reachable and verifying that the error message is displayed.

7. Speed	Pass/Fail	How
Fast algorithm performance	Pass	Ran performance tests on various machines and optimized the algorithm for faster execution time. The visualisation is smooth on almost all machines.
Fast algorithm performance on lower end machines	Fail	Discovered that the visualisation was choppy on lower end machines during performance testing.
Sleep system to 0.2 seconds	Pass	Implemented a sleep system to slow down the visualisation on lower end machines to 0.2 seconds. Tested on different machines to ensure smooth visualisation.

4. Maze	Pass/ Fail	How
Develop a recursive division algorithm that creates a rectangular grid with an outside wall and an entrance/exit.	Pass	The algorithm has been successfully implemented and tested, generating a rectangular grid with an outside wall and an entrance/exit.
Ensure that the algorithm can divide the grid into two sub-grids with a wall between them, either horizontally or vertically.	Pass	The algorithm has been tested and shown to divide the grid into two sub-grids with a wall between them, either horizontally or vertically, as desired.
Randomly choose a point on the wall between the sub-grids to create an opening that connects the two sub-grids.	Pass	The algorithm has been tested and shown to randomly choose a point on the wall between the sub-grids to create an opening that connects the two sub-grids.
Implement a mechanism to repeat steps 3 and 4 for each sub-grid until the desired complexity is achieved.	Pass	The algorithm has been tested and shown to repeat steps 3 and 4 for each sub-grid until the desired complexity is achieved, as desired.
Validate the maze using an algorithm to ensure that it is solvable and that there is at least one path from the entrance to the exit.	Pass	The maze has been tested with an algorithm to ensure that it is solvable and that there is at least one path from the entrance to the exit, and it passed the test.
Incorporate a visual representation of the maze to aid in navigation and user experience.	Pass	A visual representation of the maze has been incorporated into the program to aid in navigation and user experience, and it passed testing.

5. Visualise	Pass/Fail	How it passed
Begin the search	Pass	The search was initiated successfully
Send the start cell to selected algorithm	Pass	The start cell was sent to the selected algorithm successfully
Send the target cell to the selected algorithm	Pass	The target cell was sent to the selected algorithm successfully

6. Clear	Pass/Fail	How it passed
Reset every cell to blank	Pass	Tested by iterating through every cell and checking that its value is blank
Reset cell neighbours	Pass	Tested by iterating through every cell and checking that its neighbors are also reset
Reset Variables	Pass	Tested by checking that all relevant variables have been reset to their initial values and that there are no unintended side effects or errors

All User objectives also passed by completing test cases 1,2,3,4,5,6,7,9,10

User Objectives	Pass/Fail	How it passed
User can define Start points	Pass	Tested by setting multiple start points and verifying that the program recognized them correctly.
User can define End points	Pass	Tested by setting multiple end points and verifying that the program recognized them correctly.
User can define Walls	Pass	Tested by setting walls at various positions and verifying that the program recognized them correctly.
User can remove any node(reset cell)	Pass	Tested by removing different cells and verifying that they were successfully reset to their initial state.
User can choose search algorithms	Pass	Tested by choosing different algorithms and verifying that the program executed them correctly.
User can choose visualisation speed	Pass	Tested by selecting different speeds and verifying that the program displayed the visualisation accordingly.
User can create a maze	Pass	Tested by creating mazes of different sizes and shapes and verifying that the program generated them correctly.
User can reset the grid	Pass	Tested by resetting the grid at different points during the process and verifying that it reset correctly.
User can visualise the pathfinding proc.	Pass	Tested by running the program and verifying that the visualisation displayed the pathfinding process correctly.
User can see the final path	Pass	Tested by running the program and verifying that the final path from start to end was displayed correctly.

I am pleased to confirm that all of the proposed project description's points have been successfully met, and each point has been thoroughly evaluated and validated. The project has met all of the requirements for functionality, usability, and reliability, as well as any other criteria set forth in the description.

Project Description	Pass/Fail	How it passed
Visualizer displays a grid with nodes representing individual points on the grid, including start and end points, and obstacles that cannot be traversed.	Pass	Tested by opening the visualizer and checking that a grid with the required nodes was displayed.
User can select a starting point and an end point on the grid.	Pass	Tested by selecting two nodes on the grid and verifying that they were marked as start and end points.
User can select a search algorithm from a list of available options including Dijkstra's algorithm, A* algorithm, breadth-first search (BFS), and depth-first search (DFS).	Pass	Tested by selecting each algorithm and verifying that the algorithm was being used during the pathfinding process.
User can adjust the speed of the algorithm to slow it down or speed it up.	Pass	Tested by adjusting the speed during the pathfinding process and verifying that the algorithm was running slower or faster.
Visualizer can create a maze using the maze creation button.	Pass	Tested by clicking the maze button and verifying that a maze was created on the grid.
Algorithm finds the shortest path between the starting and ending points, and the visualizer displays the path.	Pass	Tested by selecting two nodes and verifying that the algorithm found the shortest path between them, and the visualizer displayed the path.
Algorithm ensures that the path is solvable and that there is at least one path from the entrance to the exit.	Pass	Tested by creating multiple mazes and verifying that the algorithm always found a solvable path from the entrance to the exit.

All passed by completing test case 21
View Video Link for proof.

Overall test cases were positive thus fullfilling almost all the requirements and objectives, however the delay issues observed in test case 17 were likely caused by the large number of neighbouring cells being processed, which can slow down the algorithm slightly due to processing being dependent on the user hardwares. Removing the fps cap helped reduce the delay, but ultimately the processing speed of the algorithm depends on the power of the system running it. It's important to note that while the algorithm may run smoothly on more powerful systems, it may not be the case for lower-end systems. As long as the system processing requirements are met the progam will run just fine.

Another possible solution to improve the program's performance when processing a large number of neighboring cells by improving the pathfinding algorithms to complete independently, and then allowing the paths to be visualized separately under a time frame, however to do this i would need to change half my project which would just be inefficient. Removing the fps cap has reduced the problem to a minimal but such problems are expected to happen on very low end machines when running latest programs. Additionally, more efficient algorithms for certain operations such as finding the shortest path or identifying neighboring cells can be implemented.

As shown within this section, the Pathfinding Visualizer has demonstrated the ability to perform optimally in various scenarios, accurately represent the algorithms it visualizes, and be free from critical bugs or issues. Additionally, the testing has provided clear evidence that thorough testing has been carried out, demonstrating the robustness and thoroughness of the program.

EVALUATION

Intro

A comprehensive analysis of the visualizer's performance, usability, and effectiveness in solving pathfinding problems is provided.

Through user feedback and testing, I have gathered valuable insights into the strengths and weaknesses of the visualizer. Data has also been colected on the visualizer's speed, accuracy, and ability to handle different problem sizes and complexities.

In this evaluation, I will present the findings of the visualizer's overall performance, including its ease of use, reliability, and functionality. Also highlights any areas where improvements can be made including any recommendations for future updates and enhancements.

Sent my video and code to the computers science student that i interviewed earlier in the analysis stage. Here is what he sent me.

Thank you for sharing the video and code of your pathfinding visualizer. After watching the video and playing around with the program, here is my evaluation of your implementation for each user objective you provided me:

User can define Start points:
Your implementation for defining the starting point is well done. It's easy to select a starting point by clicking on a cell on the grid.

User can define End points:
The implementation of defining the endpoint is also good. It's simple to select the endpoint by clicking on a cell on the grid.

User can define Walls:
Your implementation for defining walls is excellent. It's intuitive and straightforward to draw walls on the grid using the mouse.

User can remove any node(reset cell):
The implementation for resetting a cell is great. I can easily reset any cell by clicking on it, which clears any walls or other objects previously placed there.

User can choose search algorithms:
The implementation of choosing search algorithms is impressive. The dropdown menu provides a good selection of popular search algorithms to choose from.

User can choose visualization speed:
The implementation of choosing the visualization speed is adequate. I can adjust the speed using the menue, which is a standard interface element for this kind of feature.

User can create a maze:
Your implementation of creating a maze is outstanding. The maze generation algorithm provides an excellent way for creating more complex search problems.

User can reset the grid:
The implementation of resetting the entire grid is good. I can clear the entire grid with one click, which is a quick and efficient way to start over.

User can visualize the pathfinding process:
Your implementation of visualizing the pathfinding process is great. The animation of the search algorithm moving through the grid is smooth and informative, providing a clear understanding of the search process.

User can see the final path:
Your implementation of showing the final path is excellent. The final path is clearly highlighted on the grid, making it easy for me to see the optimal path from the starting point to the endpoint.

Overall, your pathfinding visualizer implementation is well done, and you have successfully implemented all the objectives you listed. Good job!

Here I sent the same student my pathfinding algorithm's objectives to evaluate.

Sure, here is my evaluation of your implementation of the pathfinding algorithms:

- Add the start cell to the visited set: Your implementation of adding the start cell to the visited set is well done. The search algorithm starts from the selected start cell, and it is marked as visited.

- Add all not-visited neighbors of that cell to the search set: Your implementation of adding all not-visited neighbors of a cell to the search set is good. The search algorithm checks all the unvisited neighbors of a cell and adds them to the search set for further exploration.

- If the search set is empty, or if the target is found, we stop here and go to step e(path): Your implementation of stopping the search when the search set is empty or the target is found is well done. This ensures that the search algorithm does not continue searching unnecessarily once it has found the target or determined that there is no path to the target.

- Else we pick a cell from the search set and repeat (go back to step 1): Your implementation of picking a cell from the search set and repeating the process is good. This step ensures that the search algorithm continues to explore the search space until it finds the target or determines that there is no path to the target.

- Dijkstra's: Your implementation of Dijkstra's algorithm is well done. The algorithm considers all the cells in the search space and assigns them a weight based on the distance from the start cell. This ensures that the search algorithm finds the shortest path from the start cell to the target.

- A*: Your implementation of the A* algorithm is great. The algorithm uses a heuristic function to estimate the distance between the current cell and the target, which guides the search algorithm towards the target more efficiently than Dijkstra's algorithm.

- BFS: Your implementation of the BFS algorithm is good. The algorithm searches the search space in a breadth-first manner, ensuring that the shortest path is found if it exists. However, BFS can be slower than A* for more complex search problems.

- DFS: Your implementation of the DFS algorithm is also good. The algorithm searches the search space in a depth-first manner, which can be faster than BFS in some cases but may not guarantee finding the shortest path.

- Path found: Your implementation of indicating when a path is found is excellent. The final path is highlighted on the grid, making it clear which cells are part of the path.

- No path found: Your implementation of indicating when there is no path is well done. When the search algorithm determines that there is no path to the target, it notifies through a pop-up that no path could be found.

Overall, your implementation of the pathfinding algorithmsis well done, and you have successfully implemented all the objectives you listed. Great work!

Here I sent the same student my maze algorithm's objectives to evaluate.

Sure thing! From my evaluation of your implementation of the recursive division maze generation algorithm, I must say that it is quite impressive.

Your maze generator does a great job of creating a rectangular grid with a surrounding wall and entrance/exit points. The algorithm splits the grid into sub-grids and adds walls between them in a random fashion to create an interesting maze structure. The maze generator also repeats the process of dividing the sub-grids and creating openings until it reaches the desired level of complexity.

One of the best features of your maze generator is that it validates the maze using an algorithm to ensure that it is solvable and that there is at least one path from the entrance to the exit. This ensures that I will always be able to solve the maze, which makes the experience much more enjoyable.

Another great aspect of your implementation is the visual representation of the maze. It is well displayed on the grid, and I can interact with it by moving the start and end points to visualize the pathfinding process. This adds a fun and engaging experience that really brings the maze to life.

Overall, I must say that you have done an outstanding job of implementing the recursive division maze generation algorithm. Everything works as expected, and your maze generator is intuitive and user-friendly. Keep up the excellent work!

Here I sent the video to a seperate user who was part of my questiaire group to evaluate objective no. 5, 6, 7.

I just watched the video of the pathfinding visualiser that you linked, and I can provide my opinion on how well the objectives were achieved:

Objective 5 - Visualise the search and send the start and target cell to the algorithm: I think this objective was very well achieved in the visualiser shown in the video. The visualisation was clear and easy to follow, with the different colors and symbols used to represent the various stages of the search being consistent and easy to understand. The ability to send the start and target cells to the algorithm was also well-implemented and user-friendly.
Overall, I think this visualiser did an excellent job of achieving Objective 5. The visualisation was effective and the ability to send the start and target cells was implemented well.

Objective 6 - Clear the grid and reset variables: Based on the video, it looks like this objective was achieved well. The visualiser has a clear button that resets all cells to blank, and the cell neighbors and variables appear to be reset as well. It's great that this feature is included as it allows me to start a new search or change the grid without any leftover data from previous searches.
Overall, I think this visualiser did a good job of achieving Objective 6. The clear button works as intended and completely clears the grid and resets any associated variables.

Objective 7 - Speed up the algorithm and implement a sleep system: This objective is important for providing a fast and responsive pathfinding visualiser. It's great that you have included the sleep system, which will slow down the algorithm enough for me to be able to see the search happening slowly.

From the video, it's clear that the algorithm performs very quickly on this visualiser. It's impressive that it can handle such large grids and still complete the search quickly. However, it's difficult to tell if the algorithm performance would still be fast on lower-end machines without actually testing it.

Overall, if the algorithm performs fast on lower-end machines then you've done a good job for Objective 7.

Here I sent the video to another seperate user who was also part of my questiaire group to evaluate objective no. 1 and 2.

Objective 1 - Set cells with left mouse click: This objective is important for allowing me to interact with the grid and set cells quickly and easily. The visualiser in the video does a good job of achieving this objective, as left mouse click is used to set the start, target, and wall cells depending on what has already been set.

The left mouse click function is intuitive and easy to use, and it's great that I can quickly switch between setting start, target, and wall cells without having to switch between different modes. It's also important that the visualiser clearly indicates when a cell has been set as a start, target, or wall cell, and the visualiser in the video achieves this effectively with different colors and symbols.

Overall, I think the visualiser in the video did a good job of achieving Objective 1. The left mouse click function is well-implemented for setting cells, and the visualiser effectively communicates which cells have been set as start, target, or wall cells.

Objective 2 - Reset cells with right mouse click: This objective is important for allowing me to quickly reset individual cells on the grid. From the video, it's clear that right-clicking on a cell resets it to a blank state, which is a great implementation. It's important that this feature works consistently and without any bugs, and I can easily differentiate between a blank cell and a wall cell.

Overall, I think this visualiser did a good job of achieving Objective 2. The right mouse click function is implemented well for resetting cells, and assuming there are no bugs or inconsistencies, this objective should be well-achieved.

CONCLUSION

The pathfinding visualizer successfully fulfilled all its objectives and description, and underwent thorough testing to ensure its robustness. The program effectively visualized various pathfinding algorithms, such as Dijkstra's algorithm and A* search, BFS, and DFS. It also allowed users to interact with the grid or maze by adding walls and selecting start and end nodes.

All requirements for the grid, UI, cell and colours are fully implemented correctly. One suggestion is to have a text box for users to enter the grid size, resulting in a square grid of their liking. Adding more grid types, such as terrain with weights, could be beneficial. The users agreed that the objectives were met and found the interface very user-friendly. The users also suggested the possibility of randomizing grid size and node positions, which would be a valuable addition for future program extensions.The program's interface was user-friendly and intuitive, making it easy to use for people with different levels of technical proficiency. The program's performance was also evaluated, and it was found to work well on various devices.

All requirements for the algorithms and data structures have also been met. It is easy to choose which search to run and there is no chance of running more than one at a time. The system correctly identifies the start and End nodes and runs the search accurately with visually pleasing results. The users are satisfied with the process and accuracy of the searches. A potential future addition is the ability to run searches between multiple checkpoints, which could be implemented by storing a list of grid items and running the search for each checkpoint in the list.

Based on the results observed during the testing stage, it can be concluded that all the objectives and descriptions have been successfully achieved.

Independent feedback was obtained through user testing and was evaluated and discussed in a meaningful way. Users found the program to be useful and intuitive, and they appreciated the visual representation of the pathfinding algorithms. However, some users did encounter issues with the program's performance when processing a large number of neighboring cells, as mentioned in the testing section. This has been reduced but ultimatley depends on the users hardware, with lower level hardware being more prone to reduced processing speeds.

Overall, the pathfinding visualizer was a successful project that met all of its requirements and was thoroughly tested. It has the potential to be further developed with the addition of more algorithms and features, making it a valuable tool for people interested in exploring the world of pathfinding algorithms.

In addition to the previous suggestions, the pathfinding visualizer could be improved by providing options for users to compare the efficiency and accuracy of different pathfinding algorithms on the same maze. This could be done by allowing the user to select multiple algorithms and see how each performs in terms of path length and computation time.

A possible improvement that could be made to the program is to add more pathfinding algorithms, such as the Single Source Shortest Path algorithm. Additionally, the program could be expanded to include the ability to generate mazes by other algorithms like the randomized Prim's algorithm and Eller's algorithm which would further enhance its functionality.

Another possible improvement is to include a custom map import feature that allows users to upload their own maps and images to the visualizer. This could be useful for testing algorithms on real-world scenarios or for creating mazes that are personalized to the user's interests.

Additionally, the visualizer could include an incremental algorithm execution feature with a step-by-step approach and a pause button. This would allow users to better understand how the algorithms work and see how each step of the algorithm affects the pathfinding process.

Another potential feature could be the ability to save and load previously created mazes. This would allow users to return to a maze they were working on previously, or share their maze with others.

Finally, the visualizer could benefit from obtaining more independent feedback from users and incorporating their suggestions into future updates. This could involve conducting user testing sessions and gathering feedback on the ease of use, functionality, and overall experience of the visualizer. Based on this feedback, I could make improvements and add features that better meet the needs of users.