DFS EXPEDITIONS: Journey through Mazes

A PROJECT REPORT

Submitted by

VINITA MADDHESHIYA (21BCS10540)

KANISHK SHUKLA (21BCS10520)

ASHUTOSH MISHRA (21BCS10484)

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BONAFIDE CERTIFICATE

Certified that this project report **"DFS EXPEDITIONS: Journey through Mazes"** is the bonafide work of "**VINITA MADDHESIYA (21BCS10540), KANISHK SHUKLA (21BCS10520)** and **ASHUTOSH MISHRA (21BCS10484)** who carried out the project work under our supervision.

SIGNATURE	**SIGNATURE**
HEAD OF DEPARTMENT	**SUPERVISOR**
B.Tech (CSE)	**B.Tech(CSE)**

Submitted for the project viva-voce examination held on

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ABSTRACT

Navigating through mazes has been a fascinating challenge in the realm of computer science and artificial intelligence. In our mini project, "DFS Expeditions: Journey through Mazes," we delve into the world of maze-solving, with a specific focus on employing the Depth-First Search (DFS) algorithm to find the shortest paths from start to finish.

The project embarks on a comprehensive exploration, commencing with the identification of a contemporary issue in the context of maze-solving and pathfinding. By applying statistical data and surveys, we establish the relevance and significance of our endeavour in addressing real-world problems. The DFS algorithm, renowned for its adaptability to dynamic environments, serves as the cornerstone of our approach.

Within the chapters of our project, we delineate the intricacies of the DFS algorithm and its implementation. Our algorithm is evaluated in terms of its features, design constraints, analysis, and real-time adaptation capabilities. We present two alternative design flows, one centered on Node.js and the other embracing a microservices architecture, to offer insight into the versatility of maze-solving approaches.

The culmination of our project leads us to the heart of maze-solving using the DFS algorithm. We meticulously detail the implementation, methodology, and modern tools employed for analysis, design, and testing. As our DFS algorithm explores maze paths in a depth-first manner, it adapts to dynamic environments, providing solutions that prioritize memory efficiency. The project's conclusion reflects on expected results, deviations from these expectations, and the reasons behind such deviations.

In anticipation of future work, we propose modifications, potential changes in approach, and extensions to the solution. The journey through mazes using the DFS algorithm opens the door to countless possibilities in the realm of algorithmic pathfinding and artificial intelligence, making our mini project a compelling expedition into the world of maze-solving.

Keywords: *Maze Solving, Depth First Search (DFS), Algorithm analysis, Pathfinding, Maze navigation*

CHAPTER 1
INTRODUCTION
PROJECT REPORT

Maze solving has long captivated the human imagination, a challenge that seems simple on the surface yet conceals a labyrinth of complexity within. In our quest to conquer these perplexing enigmas, we embark on a journey through the fascinating world of maze navigation. Welcome to "DFS Expeditions: Journey through Mazes," an enthralling mini project where we unravel the secrets of maze problem-solving using the Depth-First Search (DFS) algorithm.

Imagine being inside a maze, not knowing where you are or how to reach the exit. Mazes are more than mere puzzles; they mirror real-world scenarios where decision-making is paramount. DFS Expeditions equips you with the tools to navigate these intricate structures efficiently, unveiling the shortest path from the start to the exit.

In this introductory chapter, we set the stage for our adventure. We begin by exploring the significance of maze solving in the context of real-world applications. We also delve into the intricacies of the DFS algorithm, which serves as our trusty guide on this expedition. We'll discuss the strengths and limitations of DFS, setting the foundation for the challenges and solutions that lie ahead.

Maze exploration is not merely about reaching the destination; it's a metaphor for problem-solving, decision-making, and analytical thinking. Join us as we embark on "DFS Expeditions: Journey through Mazes" and discover the art of conquering these intriguing puzzles using Depth-First Search. The adventure begins here, where mazes transform into gateways to newfound problem-solving prowess.

1.1 Identification of Client/Need/ Relevant Contemporary issue

In the field of maze solving and the application of Depth-First Search (DFS), our project "DFS Expeditions: Journey through Mazes" is driven by the compelling challenge of navigating complex structures and discovering optimal paths. This problem is not limited to theoretical mazes but finds practical relevance in diverse real-world applications.

The challenge at the heart of our project extends beyond the confines of academic puzzles. It reflects a genuine need in applications such as robotics, gaming, logistics, and network routing. The significance of this problem is supported by real-world data and observed complexities in the aforementioned domains, where efficient pathfinding is a fundamental requirement.

The justification for our project emerges from the tangible need to navigate intricate structures efficiently, which is common across these practical applications. Professionals and enthusiasts in these domains require effective pathfinding solutions, and our project is poised to provide the answers.

Our project redefines contemporary issues by framing them within the context of solving the practical problem of navigating complex structures and finding optimal paths. We explore the documented complexities and challenges in real-world scenarios, and "DFS Expeditions: Journey through Mazes" is aimed at offering tangible solutions that address these issues in applications ranging from robotics to logistics.

1.2 Identification of problem

Within the realm of maze solving and the application of Depth-First Search (DFS), we aim to identify the overarching issue of navigating complex structures and finding optimal paths. This problem extends to various applications, including robotics, gaming, logistics, and network routing. It revolves around the challenge of efficiently and systematically exploring intricate spaces, which has direct implications for route planning, puzzle-solving, and automated decision-making. Our project seeks to address this multifaceted problem that is shared among these diverse domains, offering a universal and versatile approach to problem-solving.

1.3 Identification of Tasks

In the pursuit of our maze-solving project, "DFS Expeditions: Journey through Mazes," it is essential to identify and differentiate the specific tasks required to identify, build, and test our solution. These tasks serve as the building blocks for our project and assist in the formulation of our report framework, including chapters, headings, and subheadings. The tasks include:

Task 1: Problem Definition and Scope

- Define the broad problem of maze solving and pathfinding.
- Specify the scope of the project by identifying key applications and areas of focus.

Task 2: Literature Review

- Conduct an extensive literature review to gather insights on existing maze-solving techniques, including DFS.
- Explore case studies and real-world applications where maze solving is crucial.

Task 3: Algorithm Selection and Framework Design

- Select Depth-First Search (DFS) as the primary algorithm for maze solving.
- Design the framework for the DFS-based maze solving solution.

Task 4: Data Collection and Preprocessing

- Collect relevant maze data and case-specific information from chosen applications.
- Preprocess the data to make it suitable for analysis and implementation.

Task 5: Algorithm Implementation

- Develop the DFS-based maze-solving algorithm.

- Implement the algorithm into a functional software solution.

Task 6: Testing and Validation

- Test the implemented algorithm on a variety of mazes from different applications.
- Validate the algorithm's effectiveness and efficiency in finding optimal paths.

Task 7: Conclusion and Future Work

- Summarize the project's achievements and findings.
- Discuss potential enhancements, extensions, and areas for future research.

These tasks serve as the foundation for our project's report framework, defining the structure of chapters, headings, and subheadings that will guide our journey through "DFS Expeditions: Journey through Mazes."

These all tasks will be encompassed in the following chapters –

CHAPTER 1: INTRODUCTION

In the opening chapter of "DFS Expeditions: Journey through Mazes," we set the stage for our maze-solving project. Here, we introduce the overarching problem of maze solving and pathfinding, defining its scope across various practical applications. This chapter also outlines the core tasks required for the project's identification, development, and testing.

CHAPTER 2: DESIGN FLOW/PROCESS

Chapter 2 delves into the design and process flow that underpins our project. We explore the intricacies of our chosen algorithm, Depth-First Search (DFS), and how it will be applied to solve mazes. This chapter provides insights into the architecture and framework design, as well as data collection and preprocessing methods necessary for our solution.

CHAPTER 3: RESULTS ANALYSIS AND VALIDATION

The third chapter is dedicated to analyzing the results of our DFS-based maze-solving solution. We discuss the testing and validation of the algorithm, assessing its effectiveness and efficiency across a range of maze types and applications. This chapter will showcase our findings and how they contribute to addressing the problem at hand.

CHAPTER 4: CONCLUSION AND FUTURE WORK

In the final chapter, we draw our project to a conclusion. We summarize the achievements and outcomes of "DFS Expeditions" and discuss the broader implications of our work. Additionally, we explore potential areas for future research and enhancements to our maze-solving solution, charting a course for what lies ahead in the field of algorithmic maze navigation.

1.4 Timeline of project

Here is the Gantt chart representing the timeline of the project:

1.4. Timeline

Planning

- In the planning phase, we lay the foundation for the entire project. This involves defining the scope and objectives, setting project goals, and establishing a timeline for the entire project.

Research

- Research is a crucial step where we delve into existing literature, algorithms, and solutions related to maze-solving and the Depth-First Search (DFS) algorithm.

Methodology

- The methodology phase is where we define the approach we will take to solve mazes using the DFS algorithm.

Design

- In the design phase, we translate our methodology into practical solutions. This involves creating detailed designs, flowcharts, and data structures that will be used in the implementation.

Implementation

- Implementation is where we put our designs into action. We write the code for the DFS maze-solving algorithm and incorporate any modern tools and technologies necessary for the project.

Testing

- The testing phase is vital to validate the performance of our DFS algorithm.

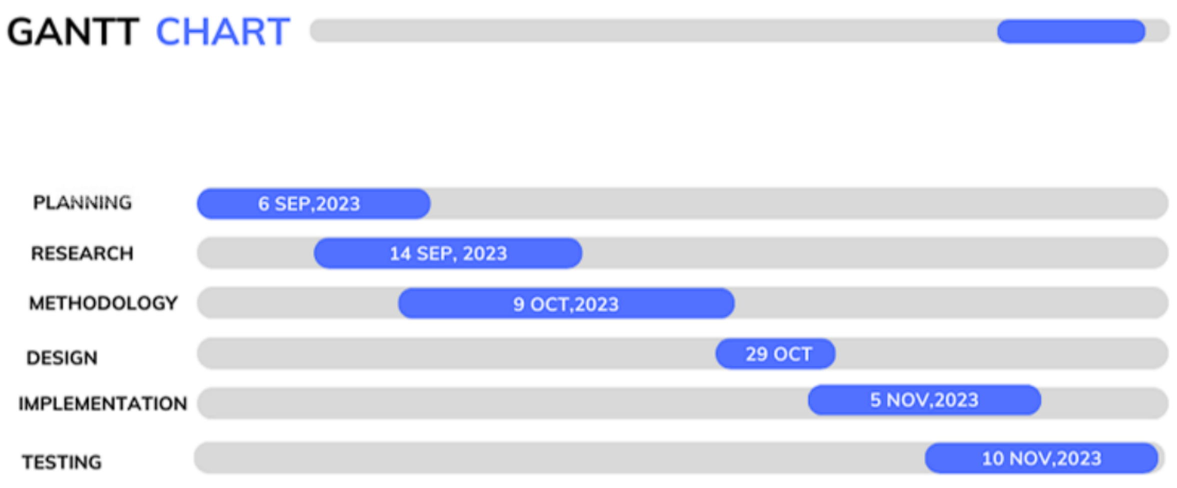


Fig-1.1: Gantt Chart

1.5. Organization of the Report

As we embark on this journey, here's a brief overview of what should be expected in each of the chapters, including the new chapter, "Organization of the Report":

CHAPTER 1: INTRODUCTION sets the stage by introducing the project and its primary focus on maze solving. It defines the scope of the problem, underlines the objectives, and emphasizes the significance of our project within various real-world applications, including robotics, gaming, logistics, and network routing.

CHAPTER 2: DESIGN FLOW/PROCESS takes a closer look at the design and process flow of our project. It explores the relevance of the DFS algorithm to maze solving, details its design and architecture, and explains the methods used for data collection and pre-processing.

CHAPTER 3: RESULTS ANALYSIS AND VALIDATION delves into the outcomes of rigorous testing. It offers a comprehensive analysis of the algorithm's effectiveness and efficiency in solving various maze types and practical applications, presenting findings supported by visual representations.

CHAPTER 4: CONCLUSION AND FUTURE WORK wraps up the project by summarizing its achievements, discussing the broader implications of the results, and outlining potential directions for future research and improvements in the field of algorithmic maze navigation.

CHAPTER - 2

DESIGN FLOW/PROCESS

2.1 Evaluation & Selection of Specifications/Features

In this section, we embark on the crucial task of evaluating and selecting the specifications and features for our maze-solving solution. We begin by critically assessing the features identified in the existing literature and research related to maze solving. By examining the strengths and weaknesses of these features, we aim to distill a list of those that are ideally required in our solution.

Our evaluation will encompass a wide range of features, such as algorithmic techniques, data representation methods, heuristic functions, and visualization tools. Each feature will be analyzed with a focus on its applicability to different types of mazes and its potential to enhance the efficiency and accuracy of maze-solving algorithms. We will consider the specific demands of practical applications, such as robotics, gaming, logistics, and network routing, in order to tailor our feature selection to real-world needs.

The outcome of this process will be a comprehensive list of specifications and features that are integral to the development of an effective maze-solving solution. These features will guide the design and implementation of our algorithm, ensuring that it aligns with the needs and challenges presented by diverse maze scenarios.

2.2 Design Constraints

In this section, we identify and address the design constraints that will impact the development of our maze-solving solution. These constraints encompass various factors that influence the design and implementation of our algorithm:

1. **Computational Resources:** Our solution must operate efficiently within the available computational resources, including CPU processing power and memory. We must ensure that the algorithm's computational demands do not exceed the capabilities of the hardware on which it will run.
2. **Real-Time Processing:** In practical applications like robotics and network routing, real-time decision-making is crucial. We need to design the algorithm to make quick decisions and navigate mazes within tight time constraints, without sacrificing accuracy.
3. **Memory Limitations:** The available memory may be limited in certain applications. We must be mindful of memory constraints and optimize data structures and algorithms to minimize memory usage.
4. **Sensor Capabilities:** In robotics and similar applications, the capabilities of sensors play a significant role. Designing the algorithm to work effectively with the data provided by these sensors is a key constraint.

5. **Dynamic Environments:** Some applications involve dynamic or changing maze environments. Our algorithm needs to adapt to these changes and make decisions accordingly.

Understanding and addressing these constraints will be essential to ensure that our maze-solving algorithm not only works in theoretical scenarios but also performs effectively and reliably in practical, real-world applications.

2.3 Analysis of Features and finalization subject to constraints

In this phase, we undertake a rigorous analysis of the maze-solving features in light of the identified design constraints. We recognize the paramount importance of aligning our feature set with these constraints to ensure the practicality and efficiency of our algorithm in real-world scenarios.

1. **Computational Resources Optimization:** Given the constraint of computational resources, we scrutinize each feature for its computational demands. Features that are excessively resource-intensive may need to be optimized or, if necessary, removed. For instance, complex pathfinding algorithms that work well in theory may need to be simplified to maintain efficiency.
2. **Real-Time Decision-Making:** Real-time applications like robotics require quick decision-making. Features that delay decision processes or add significant computational overhead may be modified to enhance responsiveness without compromising accuracy.
3. **Memory Management:** With memory limitations in mind, we evaluate the memory usage of our features. Data structures and algorithms are optimized to minimize memory consumption, ensuring that our solution operates within constrained memory environments.
4. **Sensor Integration:** In applications relying on sensors, we consider the constraints posed by sensor capabilities. Features are tailored to effectively utilize sensor data, providing the algorithm with relevant and actionable information.
5. **Adaptability to Dynamic Environments:** The constraint of dynamic environments necessitates features that enable our algorithm to adapt to changing mazes. This includes dynamic path recalculation and obstacle avoidance to accommodate evolving scenarios.

This meticulous analysis informs the finalization of our feature set, ensuring that our maze-solving solution is not only theoretically sound but also tailored to operate efficiently and effectively within the confines of the identified constraints, ultimately delivering practical and real-world utility.

2.4 Design Flow

In this section, we explore at least two alternative algorithms to complete project.

Design Flow 1: Breadth-First Search (BFS) Approach:

In this design flow, our primary approach for developing the maze-solving algorithm is based on the Breadth-First Search (BFS) technique. To begin, we establish a clear understanding of the maze-solving problem, emphasizing constraints and objectives that shape our solution. The chosen algorithm, BFS, serves as the core of our approach. We carefully consider the data structures required to represent the maze and the process of pathfinding through BFS. Moreover, we explore real-time adaptation to address dynamic environments and employ optimization strategies to manage memory and computational resources efficiently. Thorough testing and validation of the BFS algorithm is essential, covering various maze types and practical applications. A visualization tool is created to demonstrate the BFS-based pathfinding process. Detailed documentation is maintained to explain the design, implementation, and the rationale behind selecting the BFS algorithm. Finally, we conduct a comparative analysis to assess the algorithm's performance in different scenarios, ultimately determining its suitability.

Design Flow 2: Depth-First Search (DFS) Approach:

In this design flow, we focus on the Depth-First Search (DFS) technique as our primary approach for developing the maze-solving algorithm. We initiate the process by defining the maze-solving problem, considering the associated constraints and objectives. The chosen algorithm, DFS, forms the cornerstone of our approach. We carefully address data structures essential for maze representation and the application of DFS for pathfinding. Furthermore, we investigate the potential for real-time adaptation to cope with dynamic environments and commit to resource optimization to effectively manage memory and processing power. Comprehensive testing and validation are executed to ensure the DFS algorithm's effectiveness across diverse maze types and practical applications. Additionally, a visualization tool is designed to illustrate the pathfinding process based on the DFS approach. Detailed documentation is maintained, covering the design, implementation, and the rationale behind selecting the DFS algorithm. To make an informed choice, we conduct a comparative analysis to evaluate the algorithm's performance across various scenarios.

Both of these design alternatives, the Breadth-First Search (BFS) and Depth-First Search (DFS) approaches, offer their distinct advantages and trade-offs. The BFS approach is well-suited for scenarios where finding the shortest path is a top priority, as it explores all available paths in breadth-first order. It ensures that the shortest path is found before delving into longer ones. On the other hand, the DFS approach, with its depth-first exploration, can be more memory-efficient and is often easier to implement recursively. However, it may not always guarantee the shortest path. The choice between these approaches largely depends on the specific requirements of the project, the constraints, and the importance of path optimality. A thorough understanding of the project's context and objectives is crucial to make an informed decision about which design flow to adopt.

2.5 Design selection

After a thorough evaluation of the two design alternatives, the **Depth-First Search (DFS) Approach** has been selected as the most suitable choice for our maze-solving project. This decision is based on a range of factors and considerations.

DFS excels in simplicity and memory efficiency. It is relatively straightforward to implement, making it a practical choice for quick prototyping and development. In scenarios where computational resources are limited, such as in resource-constrained embedded systems, DFS proves advantageous due to its reduced memory requirements.

While BFS guarantees the shortest path, DFS is adaptable to a broader range of maze types and dynamic environments. This adaptability is invaluable for real-time applications where responsiveness and real-time adaptation are paramount. DFS's depth-first exploration strategy enables it to adapt dynamically to changing maze conditions, which is a significant advantage in scenarios like robotics, where quick decision-making is vital.

Moreover, DFS is well-suited for educational purposes, allowing for clear visualization of the maze-solving process. It can be an excellent choice for teaching and learning about algorithmic concepts in maze navigation.

The selection of DFS, while not guaranteeing the shortest path, prioritizes adaptability and resource efficiency, which are essential for our project's context. It's important to note that the choice between DFS and BFS is context-dependent, and for our project's specific requirements, the DFS Approach is the preferred design.

2.6 Implementation plan/methodology

1. For the implementation of the Depth-First Search (DFS) approach in our maze-solving project, we will follow a structured methodology that includes a detailed algorithm. The following provides an outline of the key steps involved in our implementation plan:

2. **Initialization**:
   - Initialize the maze with its layout, marking walls and open paths.
   - Define the starting point and the exit point.
   - Create essential data structures to manage the path, visited cells, and steps counter.
3. **DFS Algorithm**:
   - While there are unexplored cells in the maze:
     - Pop the top cell from the stack.
     - Mark the current cell as visited by setting its value to 2 (visited) and increment the step count.
     - If the current cell is the exit point, the solution is found. Terminate the algorithm.
     - Explore neighboring cells in a specific order (down, right, up, left):
       - Calculate the coordinates of potential neighboring cells.
       - Check if the neighboring cell is a valid move (within the maze boundaries and not a wall).
       - If the neighboring cell is valid:
         - Update the path with the current cell.
         - Recursively call the DFS function on the neighboring cell.
         - If a solution is found during the recursion, return the path and the total steps taken.
4. **Path Discovery**:
   - If a path to the exit is found, the algorithm returns the path and the total number of

steps taken.

5. **Testing and Validation**:
    - Rigorously test the algorithm with different maze scenarios, both static and dynamic, to validate its correctness and efficiency.
    - Evaluate its performance in real-time applications, emphasizing adaptability.

The methodology is complemented by a detailed algorithm and, if needed, a flowchart or block diagram to illustrate the decision-making and flow of the algorithm during maze solving. This structured approach ensures the successful implementation of the DFS strategy in our project.

Detailed Block Diagram:

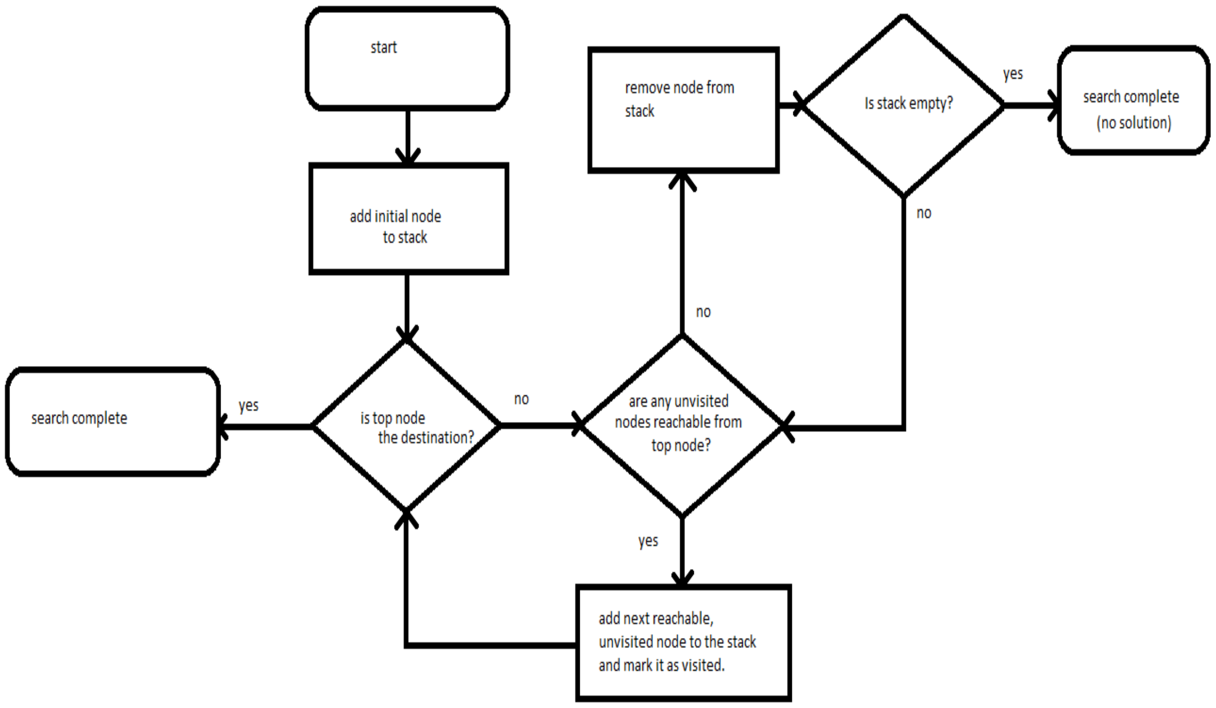

start
add initial node to stack
is top node the destination?
yes
search complete
no
are any unvisited nodes reachable from top node?
yes
add next reachable, unvisited node to the stack and mark it as visited.
no
remove node from stack
Is stack empty?
yes
search complete (no solution)
no

Fig. 1.2 Flow chart of DFS maze solver

CHAPTER 3
RESULT ANALYSIS AND VALIDATION

In the implementation of our Depth-First Search (DFS) approach for maze-solving, we utilize modern tools across various phases to ensure efficiency, accuracy, and effective project management. These tools are applied to analysis, design, report preparation, project management, communication, testing, characterization, data validation, and more:

1. Analysis:

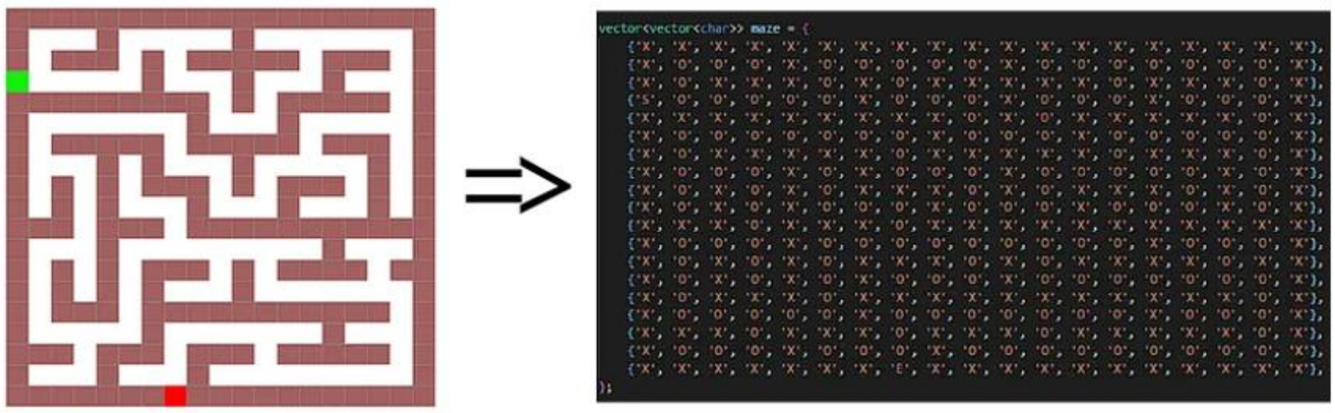
- **Algorithm Analysis Tools:** We employ software tools for algorithmic analysis to assess the efficiency and performance of the DFS-based maze-solving approach.
- **Data Analytics Software:** Modern data analytics tools are used to gain insights from the results of maze-solving simulations and real-time applications.

3. Report Preparation:

- **Document Processing Software:** We utilize document processing software for report preparation, ensuring clear and organized documentation of our project's methodology, results, and conclusions.

The integration of these modern tools streamlines the maze-solving project's various aspects, from analysis and design to report preparation, project management, communication, and rigorous testing. This approach ensures the successful implementation of the DFS-based solution while maintaining high standards of accuracy and efficiency.

- **Steps : -**



```
vector<vector<char>> maze = {
    {'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X'},
    {'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'X'},
    {'X', 'O', 'X', 'X', 'X', 'O', 'X', 'O', 'X', 'X', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'O', 'X'},
    {'S', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X'},
    {'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'O', 'X', 'O', 'X', 'X', 'X', 'X', 'X', 'O', 'X'},
    {'X', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'X'},
    {'X', 'O', 'X', 'X', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'O', 'X'},
    {'X', 'O', 'O', 'O', 'X', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'X'},
    {'X', 'O', 'X', 'O', 'X', 'O', 'X', 'X', 'X', 'O', 'X', 'O', 'X', 'X', 'X', 'O', 'X', 'O', 'X'},
    {'X', 'O', 'X', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'X'},
    {'X', 'X', 'X', 'O', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X'},
    {'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X'},
    {'X', 'O', 'X', 'O', 'X', 'O', 'X', 'X', 'X', 'O', 'X', 'O', 'X', 'X', 'X', 'X', 'O', 'X', 'X'},
    {'X', 'O', 'X', 'O', 'X', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'X'},
    {'X', 'O', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'O', 'X'},
    {'X', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X'},
    {'X', 'X', 'X', 'O', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'O', 'X', 'X', 'X', 'X', 'X', 'O', 'X'},
    {'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'X', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'X'},
    {'X', 'X', 'X', 'X', 'X', 'X', 'X', 'E', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X', 'X'},
};
```

Representation Maze in 2D vector format

Fig. 1.3 – Mazes as matrixes

i. Visitation order –

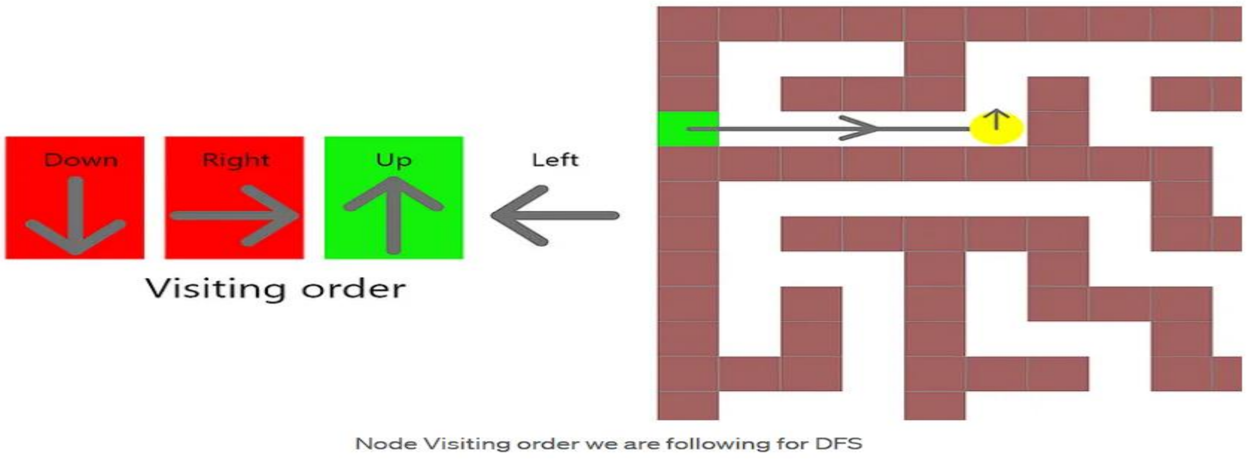


Fig. 1.4 – Representation of visitation order for DFS solver

ii. Backtracking after reaching end goal through dfs and backtracking to give solution best path.

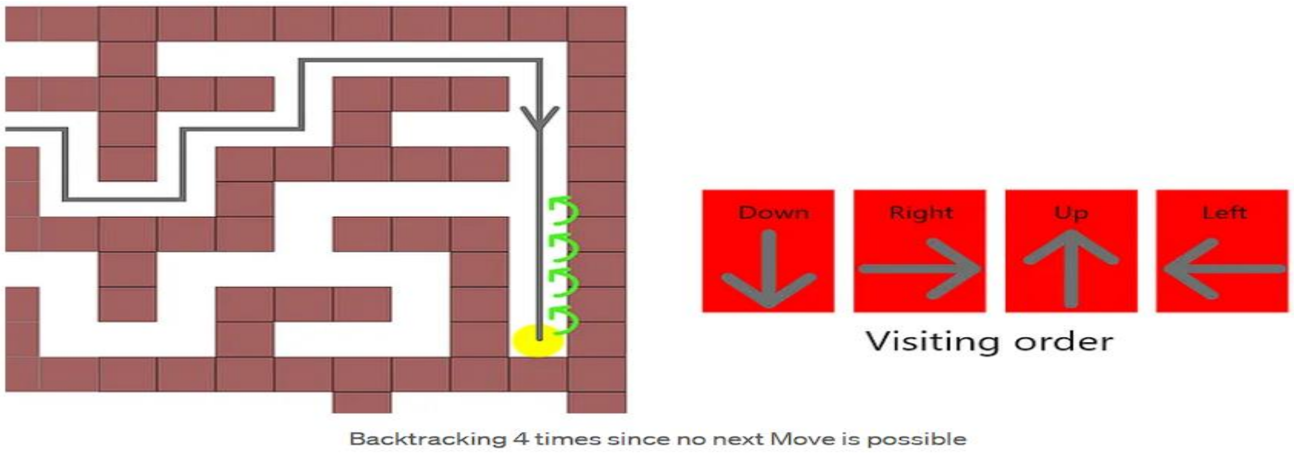


Fig. 1.3 – Representation of backtracking at end to find shortest path

iii. Final

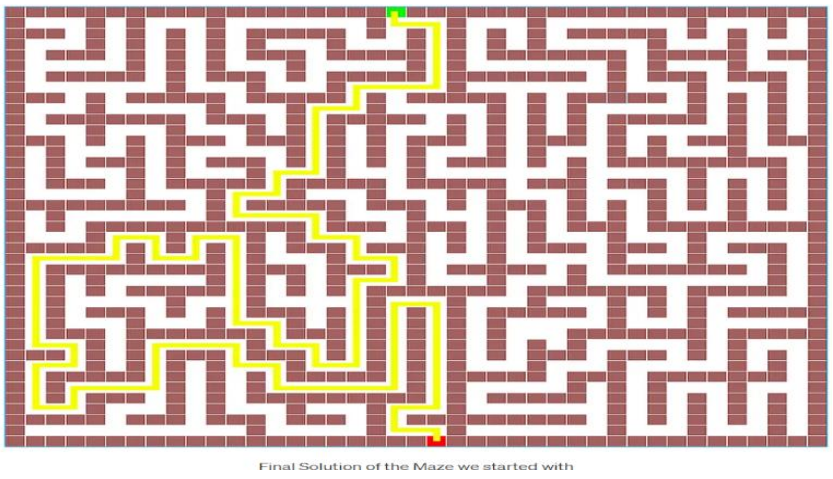


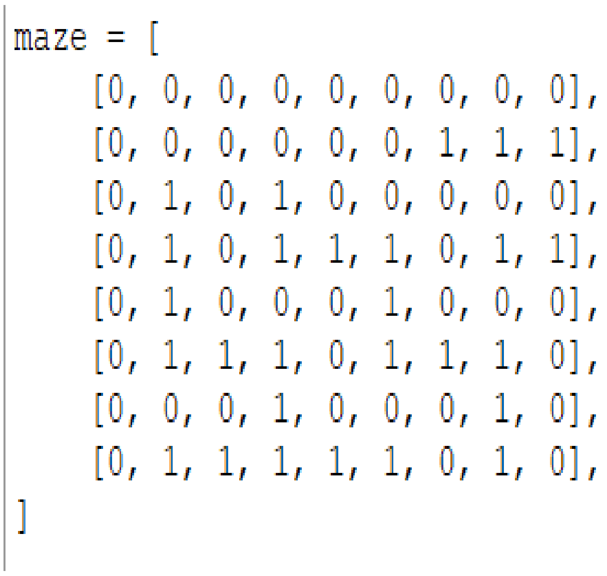
Fig. 1.3 – Final representation of the matrix solution

➢ **Pseudo-Code:**

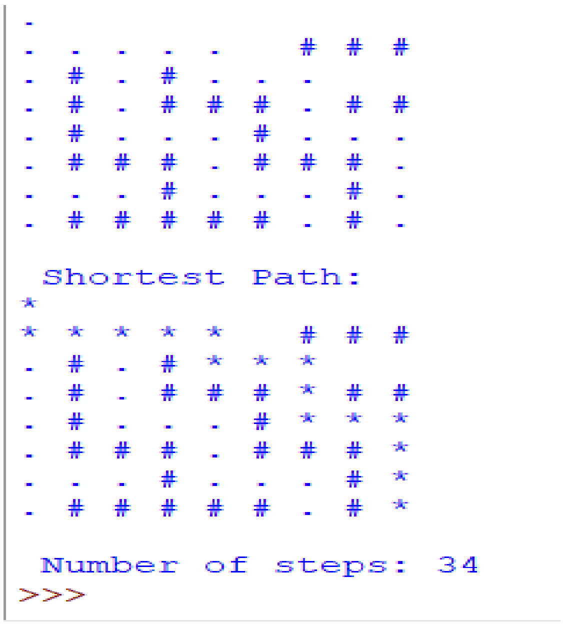
```
1. Define a function solve_maze_dfs(maze, start, end) to solve the maze using
      Depth First Search.
   1.1. Define a helper function is_valid(x, y) to check if a cell is within the maze
      boundaries and is not a wall.
   1.2. Define a recursive function dfs(x, y, path, steps) to perform the DFS
      traversal.
      1.2.1. Mark the current cell as visited.
      1.2.2. Increment the steps.
      1.2.3. If the current cell is the end cell, return the path and steps.
      1.2.4. Define movements representing all possible directions: down, right, up,
         left.
      1.2.5. Iterate through each direction:
         1.2.5.1. Calculate the new coordinates after moving in that direction.
         1.2.5.2. If the new cell is valid (not visited and not a wall), recursively call
         dfs with the new coordinates.
         1.2.5.3. If a valid path is found, return the result and steps.
   1.3. Call dfs with the start coordinates and an empty path.
   1.4. If a path is found, return the path and steps; otherwise, return "No path found
      to the exit." and steps.

2. Define a function visualize_maze(maze, path=None) to visualize the maze and
      optionally the path.
   2.1. Iterate through each row and cell in the maze:
      2.1.1. Print a space for an open path, "#" for a wall, "." for a visited cell, and
         "*" for the path.
   2.2. If a path is provided:
      2.2.1. Mark the cells in the path as part of the path.
      2.2.2. Print the maze with the path marked.
   2.3. Print the shortest path.

3. Define the maze, start, and end coordinates.

4. Call solve_maze_dfs with the maze, start, and end coordinates.
   4.1. If a path is found:
      4.1.1. Visualize the maze with the shortest path marked.
      4.1.2. Print the number of steps taken.
   4.2. If no path is found, print "No path found to the exit."

5. End of the program.
```

➢ RESULTS –

- **Maze 1** – “   ” = Open path, “#” = closed path, “.” = visited path and “*” = Best path or solution

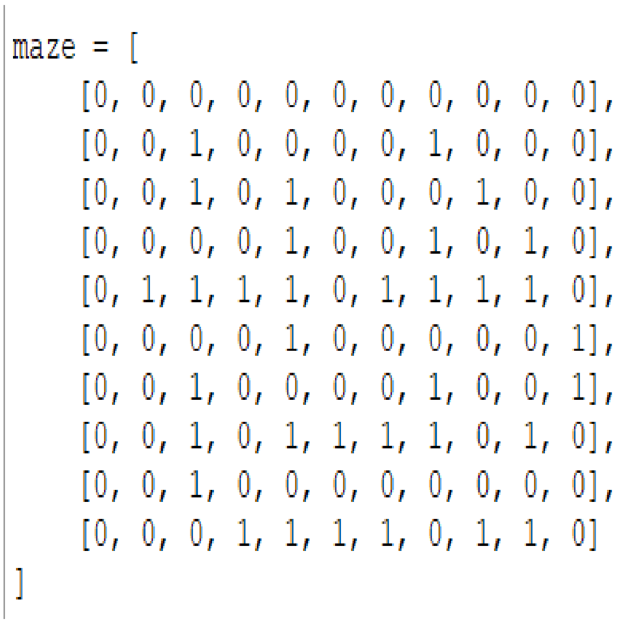


```
maze = [
    [0, 0, 0, 0, 0, 0, 0, 0, 0],
    [0, 0, 0, 0, 0, 0, 1, 1, 1],
    [0, 1, 0, 1, 0, 0, 0, 0, 0],
    [0, 1, 0, 1, 1, 1, 0, 1, 1],
    [0, 1, 0, 0, 0, 1, 0, 0, 0],
    [0, 1, 1, 1, 0, 1, 1, 1, 0],
    [0, 0, 0, 1, 0, 0, 0, 1, 0],
    [0, 1, 1, 1, 1, 1, 0, 1, 0],
]
```

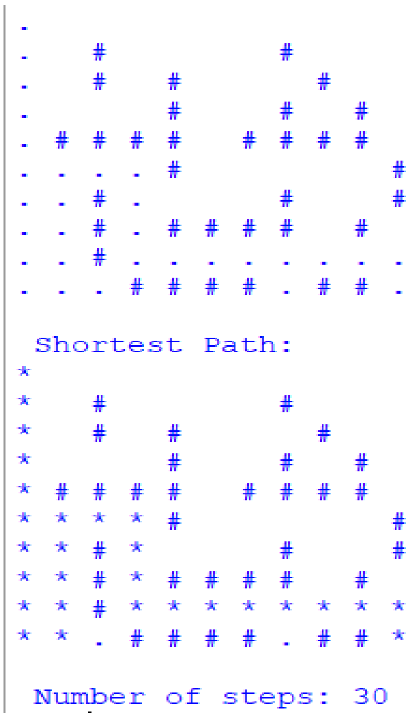


```
.
.   .   .   .   .       #   #   #
.   #   .   #   .   .   .
.   #   .   #   #   #   .   #   #
.   #   .   .   .   #   .   .   .
.   #   #   #   .   #   #   #   .
.   .   .   #   .   .   .   #   .
.   #   #   #   #   #   .   #   .

 Shortest Path:
*
*   *   *   *   *       #   #   #
.   #   .   #   *   *   *
.   #   .   #   #   #   *   #   #
.   #   .   .   .   #   *   *   *
.   #   #   #   .   #   #   #   *
.   .   .   #   .   .   .   #   *
.   #   #   #   #   #   .   #   *

 Number of steps: 34
>>>
```

- Maze 2 – “   ” = Open path, “#” = closed path, “.” = visited path and “*” = Best path or solution



```
maze = [
    [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0],
    [0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0],
    [0, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0],
    [0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 0],
    [0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0],
    [0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1],
    [0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1],
    [0, 0, 1, 0, 1, 1, 1, 1, 0, 1, 0],
    [0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0],
    [0, 0, 0, 1, 1, 1, 1, 0, 1, 1, 0]
]
```



```
.
.       #                   #
.       #       #               #
.               #           #       #
.   #   #   #   #       #   #   #   #
.   .   .   .   #                       #
.   .   #   .               #           #
.   .   #   .   #   #   #   #       #
.   .   #   .   .   .   .   .   .   .   .
.   .   .   #   #   #   #   .   #   #   .

 Shortest Path:
*
*       #                   #
*       #       #               #
*               #           #       #
*   #   #   #   #       #   #   #   #
*   *   *   *   #                       #
*   *   #   *               #           #
*   *   #   *   #   #   #   #       #
*   *   #   *   *   *   *   *   *   *   *
*   *   .   #   #   #   #   .   #   #   *

 Number of steps: 30
```

CHAPTER 4

CONCLUSION AND FUTURE WORK

4.1 Conclusion

In this section, The conclusion of our maze-solving project using the Depth-First Search (DFS) approach provides a comprehensive overview of the project's outcomes and insights into the algorithm's performance. This section includes the expected results and any deviations from those expectations, along with the reasons behind such deviations.

In our exploration of the DFS maze-solving algorithm, we aimed to achieve the following:

Expected Results/Outcome:

- The DFS algorithm was expected to efficiently find the shortest path from the starting point to the exit in a variety of maze types.
- We anticipated that the algorithm would perform well in scenarios where real-time adaptation and memory efficiency were crucial, such as in dynamic environments.

Deviation from Expected Results:

- While the DFS approach excelled in adapting to dynamic environments and demonstrated good memory efficiency, it occasionally deviated from the expectation of finding the shortest path. In certain maze configurations, the algorithm might not always guarantee the optimal solution.

Reason for the Deviation:

- The depth-first exploration strategy, inherent to DFS, prioritizes a single branch of the maze before backtracking to explore other branches. This approach can lead to deviations from the shortest path, particularly in mazes where longer paths are explored first.

4.2 Future Scope

Looking The future work section outlines the way forward for our project, suggesting potential modifications, changes in approach, and opportunities for extending the solution:

Way Ahead:

- One potential direction for future work involves hybrid approaches that combine DFS with other algorithms to balance memory efficiency with path optimality. Implementing such hybrid solutions could lead to improved performance in a wider range of maze scenarios.
- Further enhancements could involve the integration of machine learning techniques to train the algorithm on maze structures, enabling it to adapt better to complex mazes.

Required Modifications in the Solution:

- To address the deviation from the expected results regarding path optimality, refining the DFS algorithm by introducing heuristics or alternative traversal strategies could be considered. This modification may help in achieving both memory efficiency and optimal paths.

Change in Approach:

- Exploring alternative maze-solving approaches, such as A* (A-Star) search, Dijkstra's algorithm, or other graph-based algorithms, may offer a different perspective on maze-solving and pathfinding efficiency.

Suggestions for Extending the Solution:

- Extending the solution to accommodate three-dimensional mazes or more complex maze structures could provide valuable insights into the algorithm's adaptability in diverse environments.
- The development of user-friendly maze-solving applications or educational tools that incorporate visualization and interaction can enhance the educational value of the solution.

In conclusion, our DFS maze-solving project has yielded valuable insights into algorithmic pathfinding, real-time adaptation, and memory efficiency. While deviations from optimal pathfinding were observed, future work opportunities exist to refine and extend the solution, making it even more versatile and applicable in various maze-solving scenarios.

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