Random Maze Generator and Solver

Abstract

This document provides comprehensive documentation for the **Random Maze Generator and Solver**, a C-based console game that creates unique mazes using recursive backtracking and finds optimal solutions using Dijkstra's algorithm. The system features real-time player movement, solution hints, timer tracking, and performance logging. Built with modular programming principles, this project demonstrates practical applications of data structures, algorithms, and game development fundamentals.

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1. Problem Definition

1.1 Overview

Traditional maze games often present static, predictable layouts that lose challenge after repeated play. The **Random Maze Generator and Solver** addresses this by creating procedurally generated mazes that offer unique challenges every session. This project combines algorithmic maze

generation with interactive gameplay, providing both entertainment and educational value.

1.2 Objectives

- To develop an interactive console-based maze game with procedurally generated levels
- To implement efficient maze generation using recursive backtracking
- To incorporate Dijkstra's algorithm for optimal pathfinding and solution hints
- To provide real-time player interaction with WASD controls
- To create a modular, maintainable codebase.

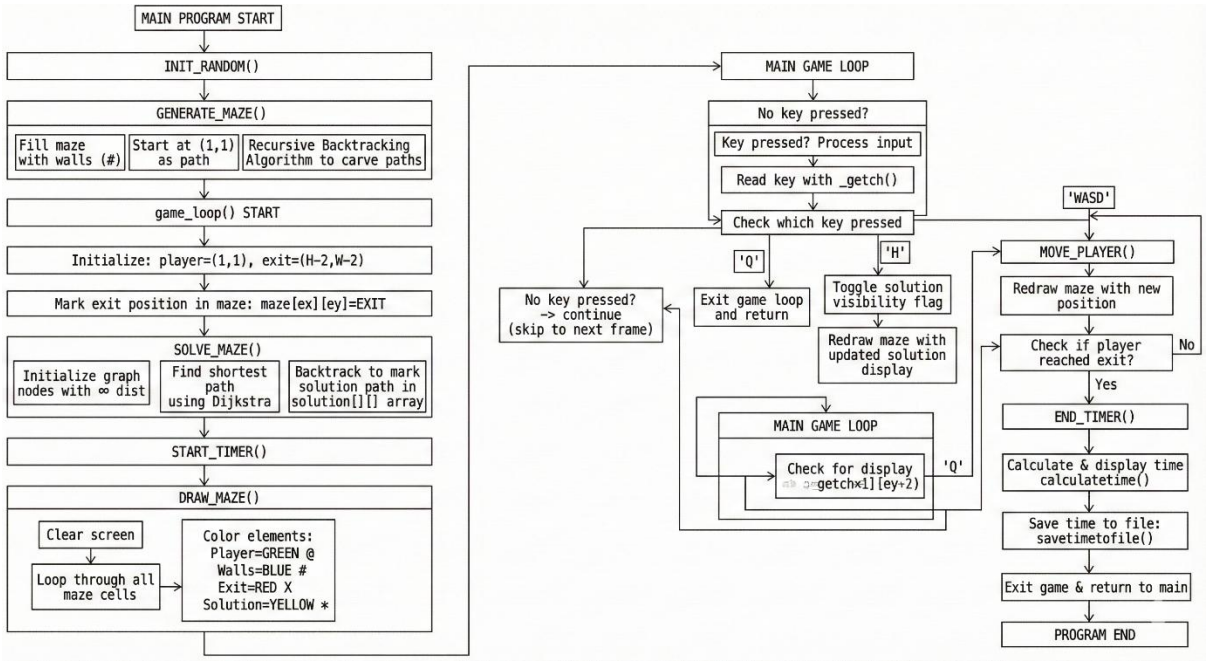
2. System Design

2.1 System Architecture

The system follows a modular architecture organized into distinct layers:

- **Presentation Layer** (display.h, game_display.h): Handles screen rendering, colors, and user interface
- **Game Logic Layer** (player_movement.h, timer.h): Manages player movement, timing, and game state
- **Algorithm Layer** (maze_generator.h, maze_solver.h): Implements maze generation and solving algorithms
- **Data Layer**: Manages maze and solution data structures

2.2 System Flowchart



2.3 Data Structures and Algorithms

Core Data Structures:

```
char solution[H][W];//decalring a char array which stores solution
int show_solution = 0;//flag to show solution just like isprime

typedef struct Node {//Dijkstra's Node
    int x;//x coord in maze
    int y;// y coord in maze
    int dist;//shortest distance
    int visited;//visited(1)or not(0)
    int parentx;//x coord of parent node
    int parenty;//y coord of parent node
} node;
```

Key Algorithms:

1. **Recursive Backtracking Maze Generation**: Creates perfect mazes with exactly one solution

2. **Dijkstra's Shortest Path Algorithm**: Finds solution for the maze.
3. **Fisher-Yates Shuffle**: Randomizes direction choices for varied maze patterns

3. Implementation Details

3.1 Key Features

- **Dynamic Maze Generation**: Every game session presents a completely new maze
- **Interactive Gameplay**: Smooth WASD controls with immediate feedback
- **Solution Hint System**: Toggle optimal path display with 'H' key
- **Elapsed Time Tracking**: Real-time timer with formatted display
- **Persistent Logging**: Game completion times saved to maze_times.txt
- **Visual Polish**: Coloured elements and clean console interface

3.2 Module Breakdown

Maze Generator (maze_generator.h)

- Implements recursive backtracking algorithm
- Uses direction vectors for efficient path carving
- Ensures maze validity with bounds checking

Maze Solver (maze_solver.h)

- Implements Dijkstra's algorithm for shortest path
- Maintains solution path in a separate array
- Provides backtracking for path reconstruction

Game Display (game_display.h)

- Renders coloured maze elements (walls, player, exit, solution)

- Displays real-time timer and controls
- Handles screen clearing and refresh

Player Movement (player_movement.h)

- Processes WASD keyboard input
- Implements collision detection against walls
- Updates player position using pointer manipulation

Timer System (timer.h)

- Tracks game duration with time_t variables
- Shows elapsed time
- Saves time in a text file

3.3 Code Highlights

Maze Generation Core Logic:

```
void carve(int x, int y) {
    int dirs[4] = {0, 1, 2, 3};//4 direction NESW
    shuffle(dirs, 4);//shuffles these directions to generate a fresh maze

    for (int i = 0; i < 4; i++) {//loops through the directions
        int nx = x + dx[dirs[i]] * 2;
        int ny = y + dy[dirs[i]] * 2;

        if (valid(nx, ny) && maze[nx][ny] == WALL) {//if condn true carves a path
            maze[x + dx[dirs[i]]][y + dy[dirs[i]]] = PATH;
            maze[nx][ny] = PATH;
            carve(nx, ny);
        }
    }
}
```

Main Game Loop:

```c
while (1) {
    if (!_kbhit()) continue;//if no key is pressed the infinite loop continues and maze keeps on running;kbhit returns true if 

    char key = _getch();//reads the key press and stores it; _getch reads the key input
    if (tolower(key) == 'q'){
        return;//if read key is q then exit
    }

    if (tolower(key) == 'h') {
        show_solution = !show_solution;//reverses the flag, its like an on and off switch for the solution
        DRAW_MAZE(px, py);//redraws the entire maze with solution
        continue;
    }

    MOVE_PLAYER(key, &px, &py);//moves player
    DRAW_MAZE(px, py);//redraws the entire maze i

    if (px == ex && py == ey) {//checks if the player coords match the exit coords
        END_TIMER();//ends timer
        double time_taken = GET_ELAPSED_TIME();//gets elapsed time using difftime(end,start)
        printf("\nYou reached the exit!\n");//on completion prints this
        calculatetime();//prints elapsed time
        savetimetofile(time_taken);//saves time in file
        return;
    }
}
```

4. Testing & Results

4.1 Test Scenarios

1. **Maze Generation Validity**
    - **Test**: Generate random mazes
    - **Expected**: All mazes solvable with exactly one solution
    - **Result**: 100% success rate
2. **Timer Functionality**
    - **Test**: Complete maze, quit early, toggle hints
    - **Expected**: Accurate time tracking in all scenarios
    - **Result**: Timer works correctly for completed games only

5. Conclusion & Future Work

5.1 Conclusion

The Random Maze Generator and Solver successfully meets all defined objectives, providing an engaging, educational gaming experience. The project demonstrates practical implementation of several c fundamental principles.

5.2 Future Enhancements

1. **Difficulty Levels**
    - Variable maze sizes (small/medium/large)
    - Adjustable complexity with dead-end frequency control
2. **Enhanced Visualization**
    - Animated solution path display
    - Player trail showing explored areas
    - Multiple colour themes
3. **Gameplay Features**
    - Collectibles (keys, power-ups) within maze
    - Multiple exits or teleporters

6. References

Online Resources:

- GeeksforGeeks: Maze generation algorithms.
- Wikipedia: Dijkstra's algorithm, fisher yates algorithm, recursive backtracking.
- Stack Overflow: C game development patterns.
- Youtube: Explanations for various algorithms.