

SPL-1 Project Report

SUDOKU ROYALE

Master the Grid, One Variant at a Time!

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1.Introduction

1.1 Project Overview

The Sudoku Game Project is an interactive and engaging graphical application developed using C++ and the SFML (Simple and Fast Multimedia Library) framework. The primary objective of this project is to provide users with a seamless and enjoyable Sudoku gaming experience by incorporating various Sudoku variations and difficulty levels.

The game offers multiple features, such as hints, mistake highlighting, and the ability to save/load game states, making it both user-friendly and accessible for players of different skill levels. Additionally, users can enjoy special Sudoku variations like Diagonal Sudoku and Windoku, adding a fresh challenge to traditional gameplay.

1.2 Objectives

The core objectives of the Sudoku Game Project are as follows:

- **Develop a User-Friendly Interface:** Utilize SFML to create an intuitive and visually appealing graphical user interface (GUI) for seamless interaction.
- **Implement Multiple Sudoku Variations:** Support different versions of Sudoku, including Traditional Sudoku, Diagonal Sudoku, and Windoku, offering diverse gameplay experiences.
- **Provide Adjustable Difficulty Levels:** Allow players to select from multiple difficulty levels (Easy, Medium, Hard, Expert) to match their skill level.
- **Enhance Gameplay with Key Features:** Include functionalities such as hints, a scoring system, and save/load capabilities to improve the user experience.
- **Ensure Robustness and Performance:** Guarantee smooth performance, responsive user input handling, and overall system reliability for a flawless gaming experience.

1.3 What is Sudoku?

Sudoku is a widely popular logic-based number puzzle that requires players to fill a 9x9 grid with digits while ensuring that each row, each column, and each of the nine 3x3 subgrids contain all digits from 1 to 9, without any repetition. The puzzle begins with a partially completed grid, and players must logically deduce the missing numbers.

1.4 How to Play Sudoku

The fundamental rules of Sudoku are as follows:

- Each row must contain the digits 1 to 9 exactly once.
- Each column must contain the digits 1 to 9 exactly once.
- Each 3x3 sub-grid (also known as a box or region) must contain the digits 1 to 9 exactly once.

Players start with a grid that has some pre-filled numbers and must use logical deduction to fill in the missing ones. No guessing is required—every puzzle has a unique solution that can be achieved through reasoning.

1.5 Sudoku Variations

The Sudoku Game Project supports multiple Sudoku variants to keep gameplay fresh and challenging:

1.5.1 Traditional Sudoku

In Traditional Sudoku, the 9x9 grid is divided into nine 3x3 subgrids. The standard Sudoku rules apply: each row, column, and subgrid must contain the numbers 1 to 9 without repetition.

1.5.2 Diagonal Sudoku

Diagonal Sudoku introduces an additional rule: both of the grid's main diagonals must also contain the digits 1 to 9 without repetition. This extra constraint increases the puzzle's complexity and requires players to think beyond rows, columns, and subgrids.

1.5.3 Windoku (Hyper Sudoku)

Windoku, also called Hyper Sudoku, includes four additional 3x3 shaded regions within the 9x9 grid. These regions must also contain the numbers 1 to 9 without repetition. This variation demands extra attention to overlapping areas and enhances the level of difficulty.

1.6 Game Features

The Sudoku Game Project includes several key features designed to enhance the gaming experience:

- **Hint System:** Provides players with suggestions for valid numbers in selected cells. The number of hints is limited to maintain challenge.
- **Save/Load Functionality:** Players can save their progress and resume their game later, ensuring continuity.
- **Scoring System:** The game calculates scores based on several factors, including difficulty level, time taken, mistakes made, and hints used.
- **End Game Screens:** Displays a congratulatory message with the final score when a puzzle is successfully completed and a game-over screen when all available attempts are exhausted.
- **Keyboard and Mouse Input Support:** Players can click on cells or use the keyboard to input numbers, making gameplay smooth and interactive.
- **Graphical Enhancements:** The interface includes visually appealing grid designs, color-coded feedback, and an easy-to-navigate menu system.

1.7 Development and Implementation

The Sudoku Game Project is implemented using C++ and SFML, with key development aspects including:

- **Graphics Handling:** SFML is used for rendering the game board, buttons, and other UI elements.
- **User Input Processing:** The game efficiently handles user interactions via mouse clicks and keyboard inputs.
- **Game Logic:** The core Sudoku logic, including puzzle validation, hint generation, and mistake tracking, is implemented in C++.
- **File Handling:** The save/load feature is achieved using file operations to store and retrieve game progress.
- **Performance Optimization:** The application is optimized to run smoothly without lag, even when handling large computations.

2. Background

2.1 History and Origin of Sudoku

Sudoku is a number puzzle game that has a rich history dating back to the late 18th century. The modern version of Sudoku that we know today was designed by Howard Garns, an American architect, and freelance puzzle constructor. It was first published in 1979 under the name "Number Place" by Dell Magazines. However, it wasn't until the game was introduced to Japan by Nikoli, a puzzle publishing company, in 1984 that it gained widespread popularity. In Japan, it was named "Sudoku," which is a shorthand for "Sūji wa dokushin ni kagiru," meaning "the digits must remain single."

The game continued to grow in popularity throughout the 1980s and 1990s, eventually spreading to other countries. By the early 2000s, Sudoku had become a global phenomenon, appearing in newspapers, magazines, and online platforms around the world. Its appeal lies in its simple rules and the logical challenge it presents, making it accessible to people of all ages and backgrounds.

2.2 Basic Rules and Gameplay

The basic rules of Sudoku are simple yet challenging. The standard Sudoku puzzle consists of a 9x9 grid divided into nine 3x3 subgrids, also known as "regions" or "boxes." The objective of the game is to fill the grid with digits from 1 to 9 in such a way that each row, each column, and each 3x3 subgrid contains all the digits from 1 to 9 without repetition.

Players start with a grid that has some cells pre-filled with numbers. The challenge is to deduce the remaining numbers by following the rules of the game. The key to solving a Sudoku puzzle is logical reasoning and pattern recognition, as players must use the given numbers to identify the correct placement of the remaining digits.

2.3 Variations of Sudoku

While the traditional 9x9 grid is the most common form of Sudoku, there are several variations that add unique challenges and constraints to the game. Some of the popular variations include:

2.3.1 Diagonal Sudoku

Diagonal Sudoku, also known as "Sudoku X," adds an extra layer of complexity by requiring that the numbers on both main diagonals (top-left to bottom-right and top-right to bottom-left) also contain all the digits from 1 to 9 without repetition. This means that in addition to rows, columns, and subgrids, the diagonals must also be considered during gameplay. Diagonal Sudoku introduces new strategies and patterns, making the puzzle-solving process more intricate and engaging.

2.3.2 Windoku

Windoku, also known as "Hyper Sudoku," includes four additional 3x3 shaded regions that must also contain the digits from 1 to 9 without repetition. These shaded regions overlap with the standard 3x3 subgrids, adding another dimension of challenge to the puzzle. The additional constraints in Windoku require players to think more critically and use advanced techniques to solve the puzzle.

2.4 Cognitive Benefits of Playing Sudoku

Sudoku is not only an enjoyable pastime but also offers several cognitive benefits. Regularly playing Sudoku can help improve various mental skills, including:

- **Logical Reasoning:** Sudoku requires players to use logical reasoning to deduce the correct placement of numbers, enhancing their problem-solving abilities.

- **Pattern Recognition:** Identifying patterns and relationships between numbers is a key aspect of solving Sudoku puzzles, which helps improve pattern recognition skills.
- **Concentration and Focus:** Successfully solving a Sudoku puzzle requires sustained concentration and focus, which can help improve attention span and mental clarity.
- **Memory:** Remembering the placement of numbers and the rules of the game can help improve short-term and working memory.

2.5 Digital Implementations of Sudoku

The rise of digital technology has led to the development of various digital implementations of Sudoku. These digital versions offer several advantages over traditional paper-based puzzles, including:

- **Interactive Features:** Digital Sudoku games often include interactive features such as hints, mistake highlighting, and undo/redo options, making the gameplay more user-friendly and engaging.
- **Customization:** Players can choose from different difficulty levels, grid sizes, and variations, allowing for a personalized gaming experience.
- **Accessibility:** Digital Sudoku games are easily accessible on various devices, including smartphones, tablets, and computers, enabling players to enjoy the game anytime and anywhere.
- **Progress Tracking:** Many digital Sudoku games include features to track players' progress, scores, and completion times, providing motivation and a sense of achievement.

2.6 The Sudoku Game Project

The Sudoku Game Project leverages the advancements in digital technology to create a comprehensive and feature-rich Sudoku gaming experience. Developed using C++ and the SFML (Simple and Fast Multimedia Library) framework, the project aims to provide a robust and interactive platform for playing Sudoku.

Key features of the Sudoku Game Project include:

- **Multiple Sudoku Variations:** Support for traditional, diagonal, and Windoku variations, providing diverse gameplay options.
- **Adjustable Difficulty Levels:** Players can choose from easy, medium, hard, and expert difficulty levels to tailor the challenge according to their preference.
- **Hint System:** A built-in hint system provides suggestions for valid numbers, helping players when they are stuck.
- **Mistake Highlighting:** Incorrect entries are highlighted in red, assisting players in identifying and correcting mistakes.
- **Save/Load Functionality:** Players can save their current game state and load it later, ensuring continuity of gameplay.
- **Scoring System:** A comprehensive scoring system that calculates scores based on the difficulty level, time taken, lives remaining, and hints used.

By combining the traditional elements of Sudoku with modern digital features, the Sudoku Game Project aims to offer an enjoyable and challenging puzzle-solving experience for players of all skill levels.

3. Description of the Project

This chapter provides a detailed description of the Sudoku Game Project, explaining the various components, functionalities, and the overall structure of the application. Flowcharts and diagrams are included where necessary to illustrate the processes and logic used in the project.

3.1 Overview

The Sudoku Game Project is designed to offer a rich and interactive Sudoku gaming experience through a graphical application. The project is developed using C++ and the SFML (Simple and Fast Multimedia Library) framework, and it includes several key features such as multiple Sudoku variations, adjustable difficulty levels, hints, mistake highlighting, and save/load capabilities.

3.2 Project Architecture

The project architecture is modular, with different components handling specific aspects of the application. The main modules include:

- **User Interface Module:** Manages the graphical user interface (GUI) and user interactions.
- **Game Logic Module:** Handles the core logic of generating, validating, and solving Sudoku puzzles.
- **File Handling Module:** Manages the saving and loading of game states.
- **Scoring System Module:** Calculates and displays the player's score based on various factors.

3.3 User Interface Module

The User Interface (UI) module is responsible for rendering the game board, buttons, and other UI elements using SFML. It also handles user inputs through mouse clicks and keyboard interactions. The main components of the UI module include:

- **Main Menu:** Provides options to start a new game, load a saved game, or exit the application.
- **Sudoku Options Menu:** Allows users to choose the type of Sudoku elements, the Sudoku version, and the difficulty level.
- **Game Interface:** Displays the Sudoku grid and allows users to interact with the puzzle, including selecting cells, entering numbers, and using hints.

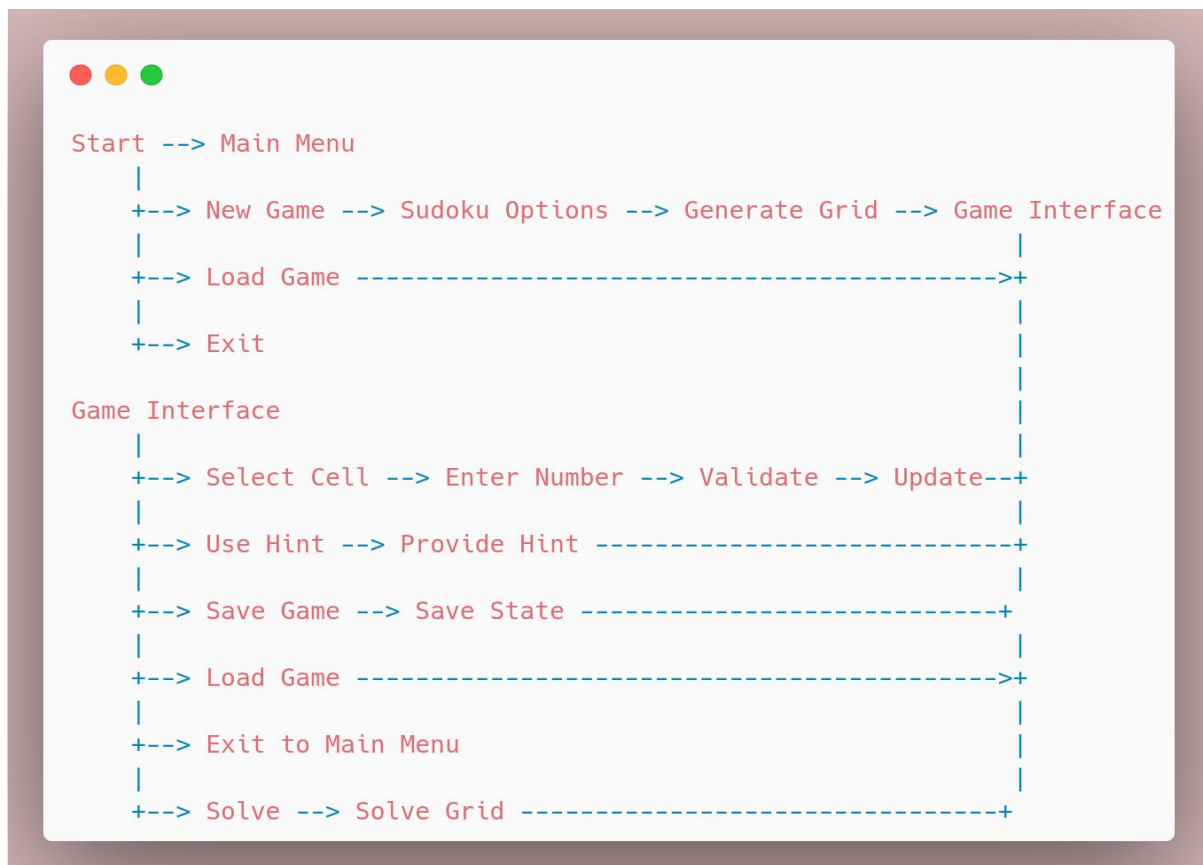


Figure 1: Flow Chart of User Interface Module

3.4 Game Logic Module

The Game Logic module handles the generation, validation, and solving of Sudoku puzzles. The module includes functions for:

- Generating Sudoku Grids: Creates a valid Sudoku grid based on the chosen Sudoku variation and difficulty level.
- Validating Entries: Checks if the entered number is valid according to Sudoku rules.
- Providing Hints: Suggests valid numbers for selected cells.
- Solving the Puzzle: Uses backtracking and advanced techniques like X-Wing and Swordfish to solve the Sudoku grid.

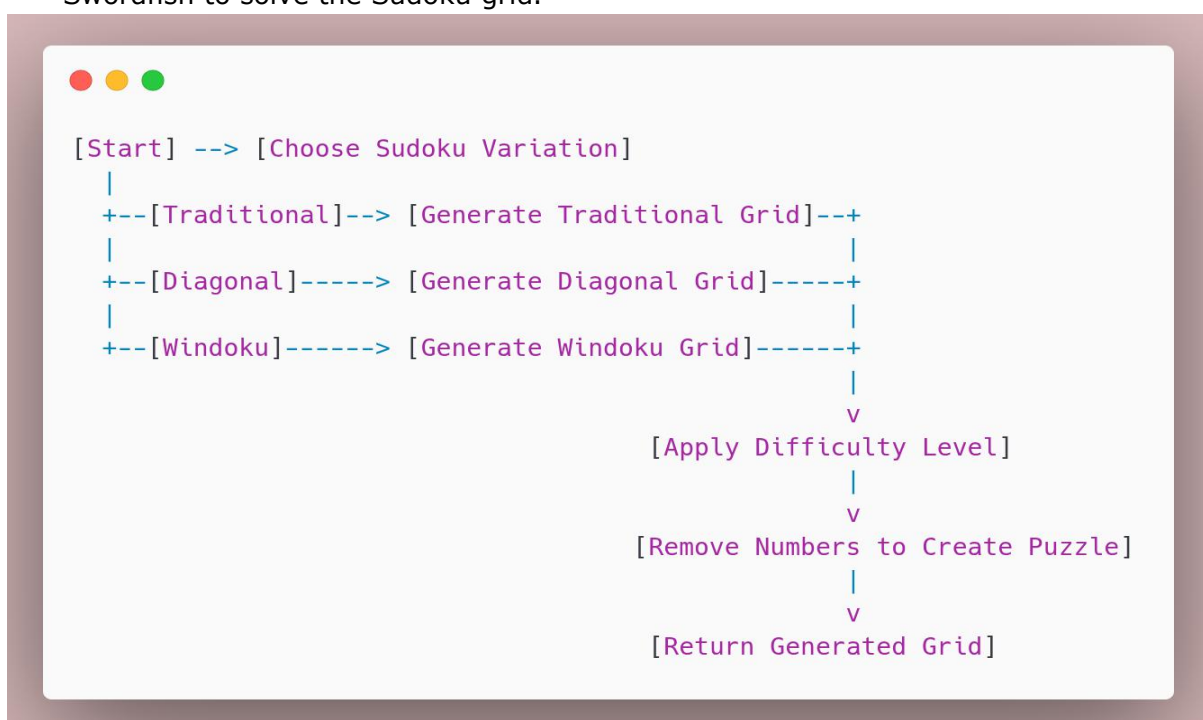


Figure 2: Flow Chart of Game Logic Module

3.5 File Handling Module

The File Handling module manages the saving and loading of game states. It includes functions to:

- **Save Game State:** Stores the current state of the Sudoku grid, lives, hints used, and elapsed time to a file.
- **Load Game State:** Retrieves the saved state from a file and restores the game to the saved state.

3.6 Scoring System Module

The Scoring System module calculates the player's score based on various factors, including the difficulty level, time taken, lives remaining, and hints used. It displays the final score upon completion of the puzzle or when the game is over.

3.7 Additional Features

The Sudoku Game Project includes several additional features to enhance the gaming experience:

- **Mistake Highlighting:** Highlights incorrect entries in red, helping users identify and correct mistakes.
- **End Game Screens:** Displays congratulatory messages and final scores when a puzzle is successfully completed, and game-over screens when all lives are exhausted.
- **Graphical Enhancements:** Includes visually appealing grid designs, color-coded feedback, and an easy-to-navigate menu system.

3.8 Future Enhancements

Potential future enhancements for the Sudoku Game Project include:

- **Multiplayer Mode:** Allowing multiple players to compete or collaborate in solving Sudoku puzzles.
- **Custom Puzzle Creation:** Enabling users to create and share their own Sudoku puzzles.
- **Advanced Analytics:** Providing detailed statistics and analytics on puzzle-solving techniques and performance.
- **Mobile Compatibility:** Adapting the application for mobile devices to reach a broader audience.

4. Implementation and Testing

This chapter describes the implementation and testing of the Sudoku Game Project. It includes detailed explanations of the key components, functions, and testing strategies used to ensure the robustness and performance of the application.

4.1 Implementation Details

- **Graphical User Interface:** Developed using SFML, the GUI allows for intuitive **Sudoku Grid Generation:** Algorithms for creating valid Sudoku grids, including variations like Diagonal Sudoku and Windoku.
- **User Input Handling:** Efficiently processes user interactions via mouse clicks and keyboard inputs.
- **Game Logic:** Core logic for validating, solving, and providing hints for Sudoku puzzles.
- **File Handling:** Manages the saving and loading of game states.
- **Scoring System:** Calculates and displays the player's score based on various factors.

4.1.1 Graphical User Interface

The graphical user interface is implemented using SFML to create an intuitive and visually appealing environment for the player. The main components include the main menu, options menu, and game interface.



```
void drawMainMenu(RenderWindow &window, Font &font) {
    Text title;
    title.setFont(font);
    title.setString("Sudoku Game");
    title.setCharacterSize(48);
    title.setFillColor(Color::Black);
    title.setPosition(200, 100);
    window.draw(title);

    drawButton(window, font, "New Game", Vector2f(300, 300), Color::Green);
    drawButton(window, font, "Load Game", Vector2f(300, 400), Color::Blue);
}
```

Figure 3: Code Snippet for Drawing main menu

```

void drawSudokuOptions(RenderWindow &window, Font &font) {
    Text text;
    text.setFont(font);
    text.setCharacterSize(24);
    text.setFillColor(Color::Black);

    text.setString("Choose Sudoku Elements:");
    text.setPosition(50, 50);
    window.draw(text);

    drawButton(window, font, "Traditional", Vector2f(50, 100), numTypeChoice == 1 ? Color::Green :
Color::White);
    drawButton(window, font, "Odd Num", Vector2f(300, 100), numTypeChoice == 2 ? Color::Green : Color::White);
    drawButton(window, font, "Even Num", Vector2f(50, 200), numTypeChoice == 3 ? Color::Green : Color::White);
    drawButton(window, font, "Alphabet", Vector2f(300, 200), numTypeChoice == 4 ? Color::Green : Color::White);

    text.setString("Choose Sudoku Version:");
    text.setPosition(50, 300);
    window.draw(text);

    drawButton(window, font, "General", Vector2f(50, 350), sudokuTypeChoice == 1 ? Color::Green : Color::White);
    drawButton(window, font, "Diagonal", Vector2f(300, 350), sudokuTypeChoice == 2 ? Color::Green :
Color::White);
    drawButton(window, font, "Windoku", Vector2f(50, 450), sudokuTypeChoice == 3 ? Color::Green : Color::White);

    text.setString("Choose Difficulty Level:");
    text.setPosition(50, 550);
    window.draw(text);

    drawButton(window, font, "Easy", Vector2f(50, 600), difficultyChoice == 1 ? Color::Green : Color::White);
    drawButton(window, font, "Medium", Vector2f(300, 600), difficultyChoice == 2 ? Color::Green : Color::White);
    drawButton(window, font, "Hard", Vector2f(50, 700), difficultyChoice == 3 ? Color::Green : Color::White);
    drawButton(window, font, "Expert", Vector2f(300, 700), difficultyChoice == 4 ? Color::Green : Color::White);
}

```

Figure 4: Code Snippet for Drawing Sudoku Options

```

void drawGrid(RenderWindow &window, const vector<vector<int>> &grid) {
    Font font;
    if (!font.loadFromFile("/usr/share/fonts/truetype/dejavu/DejaVuSans.ttf")) {
        cerr << "Error loading font" << endl;
        return;
    }

    for (int row = 0; row < GRID_SIZE; row++) {
        for (int col = 0; col < GRID_SIZE; col++) {
            RectangleShape cell(Vector2f(60, 60));
            cell.setPosition(col * 60 + 100, row * 60 + 50);
            cell.setOutlineThickness(1);
            cell.setOutlineColor(Color::Black);

            // Highlight Windoku subgrids
            if ((row >= 1 && row <= 3 && col >= 1 && col <= 3) ||
                (row >= 1 && row <= 3 && col >= 5 && col <= 7) ||
                (row >= 5 && row <= 7 && col >= 1 && col <= 3) ||
                (row >= 5 && row <= 7 && col >= 5 && col <= 7)) {
                cell.setFillColor(Color(200, 200, 200));
            }

            if (row == selectedRow && col == selectedCol) {
                cell.setFillColor(Color(150, 150, 150));
            }
            window.draw(cell);

            if (grid[row][col] != 0) {
                Text text;
                text.setFont(font);
                if (numTypeChoice == 4) {
                    char ch = grid[row][col] + 'A' - 1;
                    text.setString(string(1, ch));
                } else {
                    text.setString(to_string(grid[row][col]));
                }
                text.setCharacterSize(24);
                if (highlightMistakes && !isCorrect(row + 1, col + 1, grid[row][col])) {
                    text.setFillColor(Color::Red);
                } else {
                    text.setFillColor(Color::Black);
                }
                text.setPosition(col * 60 + 120, row * 60 + 60);
                window.draw(text);
            }
        }
    }

    // Draw thicker lines for 3x3 subgrid boundaries
    RectangleShape thickLine(Vector2f(540, 3)); // Horizontal line
    thickLine.setFillColor(Color::Black);
    for (int i = 1; i < 3; i++) {
        thickLine.setPosition(100, i * 180 + 50);
        window.draw(thickLine);
    }

    thickLine.setSize(Vector2f(3, 540)); // Vertical line
    for (int i = 1; i < 3; i++) {
        thickLine.setPosition(i * 180 + 100, 50);
        window.draw(thickLine);
    }
}

```

Figure 5: Code Snippet for Drawing Sudoku Grid

4.1.2 Sudoku Grid Generation


The Sudoku grid generation is a crucial part of the game logic. It involves creating a valid Sudoku grid based on the chosen variation and difficulty level.

```
vector<vector<int>> generateSudoku() {
    vector<vector<int>> grid(GRID_SIZE, vector<int>(GRID_SIZE, 0));
    if(sudokuTypeChoice == 1) {
        fillGrid(grid);
    }
    else if(sudokuTypeChoice == 2){
        fillDiagonalSudokuGrid(grid);
    }
    else if(sudokuTypeChoice == 3){
        fillWindokuGrid(grid);
    }
    else {
        cout << "Invalid Choice. Defaulting to general sudoku." << endl;
        fillGrid(grid);
    }

    int holes;
    switch (difficultyChoice) {
        case 1:
            holes = 25;
            break;
        case 2:
            holes = 30;
            break;
        case 3:
            holes = 40;
            break;
        case 4:
            holes = 50;
            break;
        default:
            cout << "Invalid choice, defaulting to Medium.\n";
            holes = 30;
    }

    solvedGrid = grid;
    removeNumbers(grid, holes);
    return grid;
}
```

Figure 6: Code Snippet for Generating Sudoku Grid




```

bool isValid(vector<vector<int>>& grid, int row, int col, int num) {
    for (int i = 0; i < GRID_SIZE; i++) {
        if (grid[row][i] == num || grid[i][col] == num) {
            return false;
        }
        if (grid[row / 3 * 3 + i / 3][col / 3 * 3 + i % 3] == num) {
            return false;
        }
    }
    return true;
}

```

Figure 7: Code Snippet for Validating Sudoku Entries



```

bool fillGrid(vector<vector<int>>& grid) {
    shuffleNumbers(NUMBERS);
    for (int row = 0; row < GRID_SIZE; row++) {
        for (int col = 0; col < GRID_SIZE; col++) {
            if (grid[row][col] == 0) {
                for (int num : NUMBERS) {
                    if (isValid(grid, row, col, num)) {
                        grid[row][col] = num;
                        if (fillGrid(grid)) {
                            return true;
                        }
                        grid[row][col] = 0;
                    }
                }
            }
        }
    }
    return false;
}
return true;
}

```

Figure 8: Code Snippet for Filling Sudoku Grid


```

bool fillDiagonalSudokuGrid(vector<vector<int>>& grid) {
    for (int row = 0; row < GRID_SIZE; row++) {
        for (int col = 0; col < GRID_SIZE; col++) {
            if (grid[row][col] == 0) {
                for (int num : NUMBERS) {
                    if (isDiagonalSudokuValid(grid, row, col, num)) {
                        grid[row][col] = num;
                        if (fillDiagonalSudokuGrid(grid)) {
                            return true;
                        }
                        grid[row][col] = 0;
                    }
                }
                return false;
            }
        }
    }
    return true;
}

```

Figure 9: Code Snippet for Filling Diagonal Sudoku Grid

```

bool fillWindokuGrid(vector<vector<int>>& grid) {
    // Don't need to use shuffle numbers here
    for (int row = 0; row < GRID_SIZE; row++) {
        for (int col = 0; col < GRID_SIZE; col++) {
            if (grid[row][col] == 0) {
                for (int num : NUMBERS) {
                    if (isValidWindoku(grid, row, col, num)) {
                        grid[row][col] = num;
                        if (fillWindokuGrid(grid)) {
                            return true;
                        }
                        grid[row][col] = 0; // Backtrack
                    }
                }
                return false; // No valid number found
            }
        }
    }
    return true; // Grid filled successfully
}

```

Figure 10: Code Snippet for Filling Windoku Grid

4.1.3 User Input Handling

User input handling is essential for interactive gameplay. The game processes user interactions via mouse clicks and keyboard inputs, allowing players to select cells, enter numbers, and use hints.

4.1.4 Game Logic

The core game logic includes functions for validating, solving, and providing hints for Sudoku puzzles.

```
void provideHint(const vector<vector<int>>& grid) {
    int minChoices = GRID_SIZE + 1;
    int bestRow = -1, bestCol = -1;
    vector<int> bestChoices;

    for (int row = 0; row < GRID_SIZE; ++row) {
        for (int col = 0; col < GRID_SIZE; ++col) {
            if (grid[row][col] == 0) {
                vector<int> validNumbers = getValidNumbers(row, col, grid);
                if (validNumbers.size() < minChoices) {
                    minChoices = validNumbers.size();
                    bestRow = row;
                    bestCol = col;
                    bestChoices = validNumbers;
                }
            }
        }
    }

    if (bestRow != -1 && bestCol != -1) {
        cout << "Greedy Hint: Cell (" << bestRow + 1 << ", " << bestCol + 1 << ") has "
              << bestChoices.size() << " valid choices left. Suggested number: "
              << bestChoices[0] << endl;
    }
}
```

Figure 11: Code Snippet for Providing Hints

```

bool solveSudoku(vector<vector<int>>& grid) {
    for (int row = 0; row < GRID_SIZE; row++) {
        for (int col = 0; col < GRID_SIZE; col++) {
            if (grid[row][col] == 0) {
                for (int num = 1; num <= 9; num++) {
                    if (isValid(grid, row, col, num)) {
                        grid[row][col] = num;
                        if (solveSudoku(grid)) return true;
                        grid[row][col] = 0;
                    }
                }
                return false;
            }
        }
    }
    return true;
}

```

Figure 12: Code Snippet for Solving Sudoku Grid

4.1.5 File Handling

File handling functions manage the saving and loading of game states, allowing players to save their progress and resume later.

```

void saveSudoku(vector<vector<int>> &grid, int lives, Time elapsedTime) {
    ofstream outFile("saved.txt");
    if (!outFile) {
        cerr << "Error opening file!" << endl;
        return;
    }

    for (const auto &row : grid) {
        for (int num : row) {
            outFile << num << " ";
        }
        outFile << endl;
    }

    outFile << "Lives: " << lives << endl;
    outFile << "Time: " << elapsedTime.asSeconds() << endl;

    outFile.close();
    cout << "Sudoku grid, lives, and time saved successfully." << endl;
}

```

Figure 13: Code Snippet for Saving Game State

```

void loadSudoku(vector<vector<int>> &grid, int &lives, Time &elapsedTime) {
    ifstream inFile("saved.txt");
    if (!inFile) {
        cerr << "Error opening file!" << endl;
        return;
    }

    for (auto &row : grid) {
        for (int &num : row) {
            inFile >> num;
        }
    }

    string livesLabel;
    inFile >> livesLabel >> lives;

    string timeLabel;
    float seconds;
    inFile >> timeLabel >> seconds;
    elapsedTime = sf::seconds(seconds);

    inFile.close();
    cout << "Sudoku grid, lives, and time loaded successfully." << endl;
}

```

Figure 14: Code Snippet for Loading Game State

4.1.6 Scoring System

The scoring system calculates the player's score based on various factors such as lives remaining, hints used, and time taken.

```

int calculateScore(int lives, int hintsUsed, Time totalTime, int difficultyChoice) {
    int baseScore;
    switch (difficultyChoice) {
        case 1:
            baseScore = 1500; // Easy
            break;
        case 2:
            baseScore = 2000; // Medium
            break;
        case 3:
            baseScore = 2500; // Hard
            break;
        case 4:
            baseScore = 3000; // Expert
            break;
        default:
            baseScore = 1500; // Default to Easy
    }
    int timePenalty = static_cast<int>(totalTime.asSeconds()) / 60;
    int hintPenalty = hintsUsed * 25;
    int livesBonus = lives * 100;
    return baseScore - timePenalty - hintPenalty + livesBonus;
}

```

Figure 15: Code Snippet for Calculating Score

4.2 Testing Details

Testing is a critical phase in the development process to ensure the functionality, robustness, and performance of the Sudoku Game Project. Various testing strategies were employed, including unit testing, integration testing, and user acceptance testing.

4.2.1 Unit Testing

Unit testing involves testing individual components and functions to ensure they work as expected. Key functions tested include grid generation, validation, and user input handling.

4.2.2 Integration Testing

Integration testing ensures that different components of the application work together seamlessly. This includes testing the interaction between the user interface, game logic, and file handling modules.

4.3 Performance Optimization

Performance optimization ensures the application runs smoothly without lag, even when handling large computations. Techniques used include efficient algorithms for grid generation and validation, and optimizing rendering in SFML.

4.4 Future Testing Enhancements

Potential future enhancements for testing include:

- **Automated Testing:** Implementing automated testing frameworks to streamline the testing process and ensure consistent coverage.
- **Stress Testing:** Performing stress testing to evaluate the application's performance under extreme conditions.
- **Continuous Integration:** Integrating continuous testing into the development pipeline to catch issues early and maintain code quality.

The implementation and testing phases of the Sudoku Game Project have ensured a robust and enjoyable gaming experience for users. Through detailed testing and optimization, the project delivers a high-quality Sudoku game that meets user expectations.

5. User Interface

This chapter provides a detailed description of the user interface (UI) of the Sudoku Game Project. The UI is designed to be intuitive and user-friendly, allowing players to easily navigate through the game and interact with various features. Sample inputs and outputs are provided to illustrate the functionality.

5.1 Main Menu

The main menu is the starting point of the game, providing options for the player to start a new game, load a saved game, or exit the application.



Figure 16: Image of Main Menu

5.2 Sudoku Options Menu

The options menu allows players to choose the type of Sudoku elements, the Sudoku version, and the difficulty level before starting a new game.

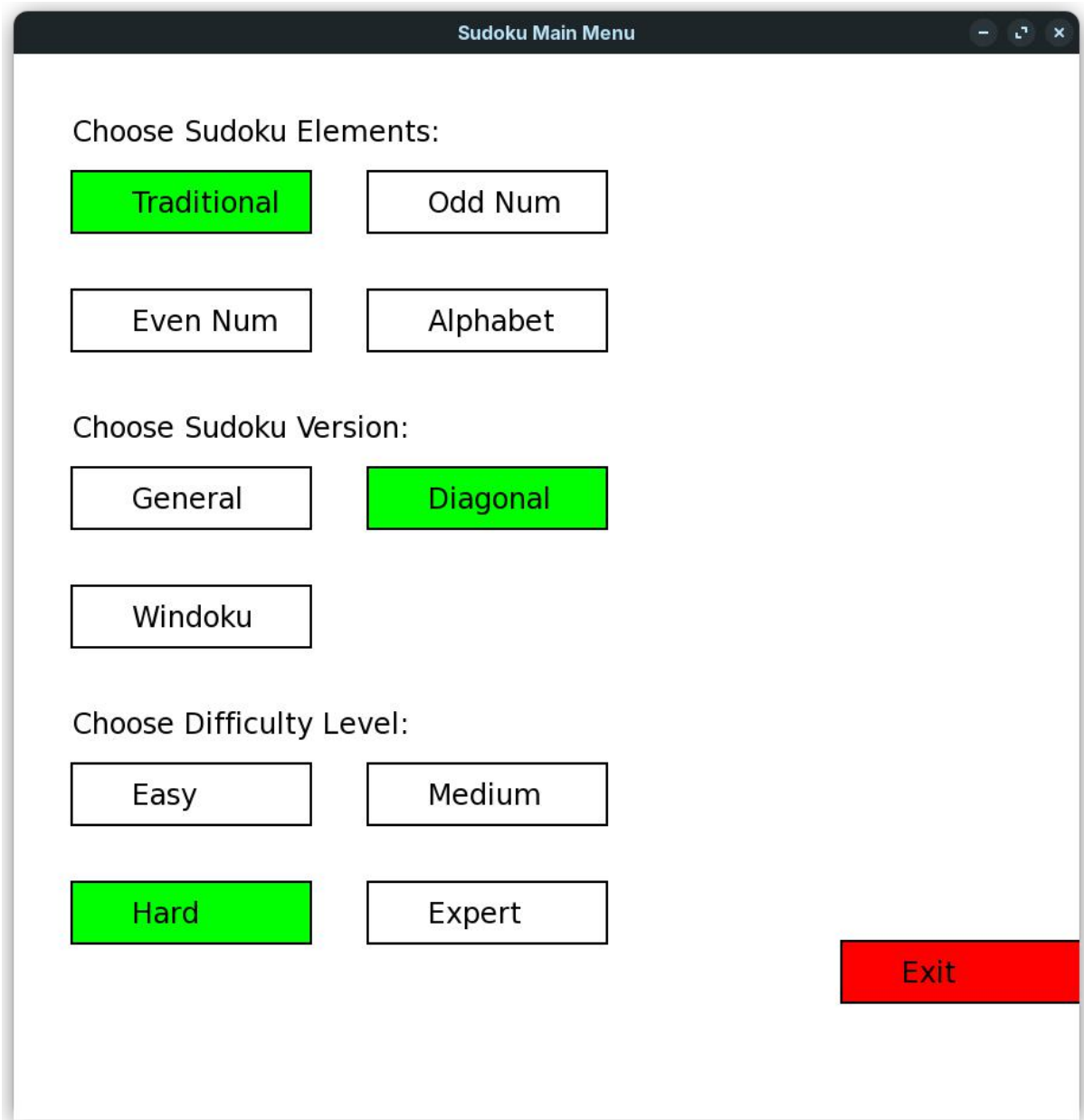


Figure 17: Image of Sudoku Option Menu

5.3 Game Interface

The game interface is where players interact with the Sudoku grid. It includes the grid itself, buttons for various actions, and displays for hints, lives, and the timer.

5.3.1 Sudoku Grid

The Sudoku grid is the main component where players fill in the numbers. The grid highlights the selected cell and shows mistake highlighting if enabled.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 8 | 2 | 7 | 9 | 3 | | |
| | 7 | 9 | 3 | | 5 | 6 | 1 | 8 |
| 3 | | | | | | 2 | 7 | |
| | 6 | 2 | 8 | 9 | 7 | 4 | 5 | 3 |
| 8 | 9 | 4 | | 3 | | 7 | 6 | 2 |
| | 5 | 3 | 4 | | 2 | 9 | 8 | 1 |
| 5 | | 6 | 9 | 8 | 4 | | 3 | |
| | 8 | 1 | | | | 5 | 9 | 6 |
| | 3 | 7 | 1 | | 6 | 8 | 2 | |

Figure 18: Image of Sudoku Grid

5.3.2 Action Buttons

The action buttons allow players to save the game, load a saved game, request a hint, solve the puzzle, restart the game, return to the main menu, or exit the application.

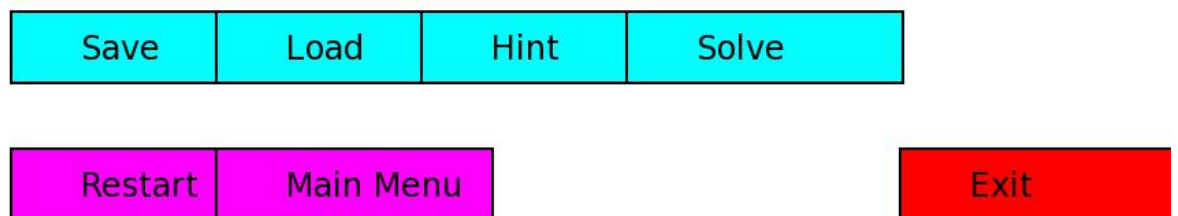


Figure 19: Image of Action Buttons

5.3.3 Hint System

The hint system provides players with suggestions for valid numbers in selected cells. The number of hints is limited to maintain the challenge.

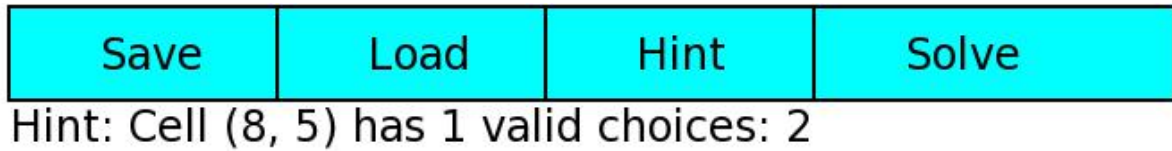


Figure 20: Image of Giving Hint using SFML

5.3.4 Lives Display

The lives display shows the number of lives remaining, represented by heart icons.



Figure 21: User Interface of Displaying Lives

5.3.5 Timer

The timer shows the elapsed time since the game started.

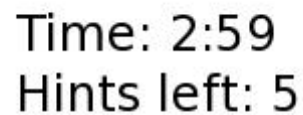


Figure 22: Image of Game Timer

5.4 End Game Screens

The end game screens include the game-over screen and the congratulatory screen. These screens are displayed when the player either wins the game or runs out of lives.

5.4.1 Game-Over Screen

The game-over screen displays a message indicating that the player has run out of lives and the game is over.

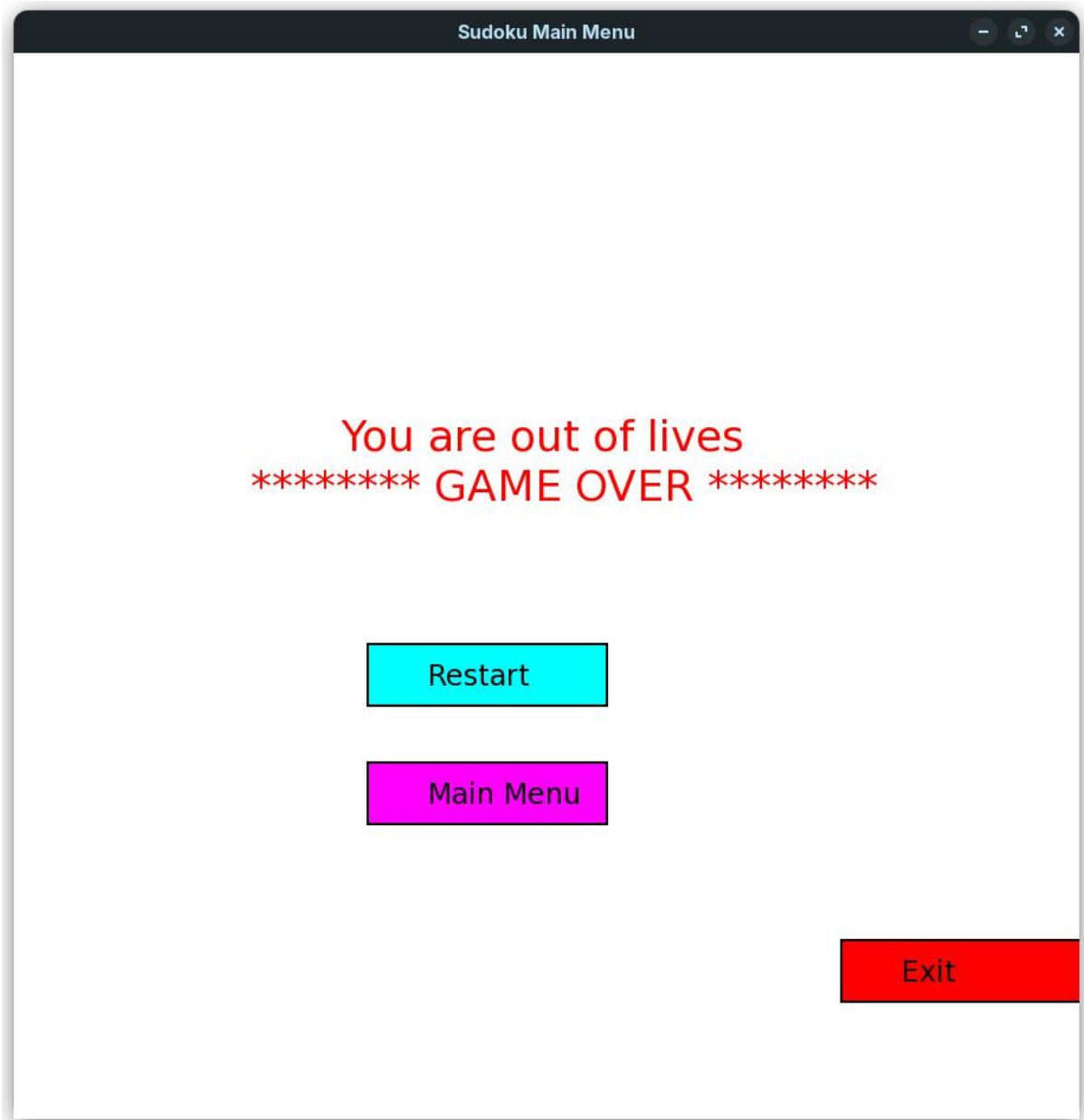


Figure 23: Image of Game Over Screen

5.4.2 Congratulatory Screen

The congratulatory screen displays a message congratulating the player for successfully completing the puzzle, along with the final score and time taken.

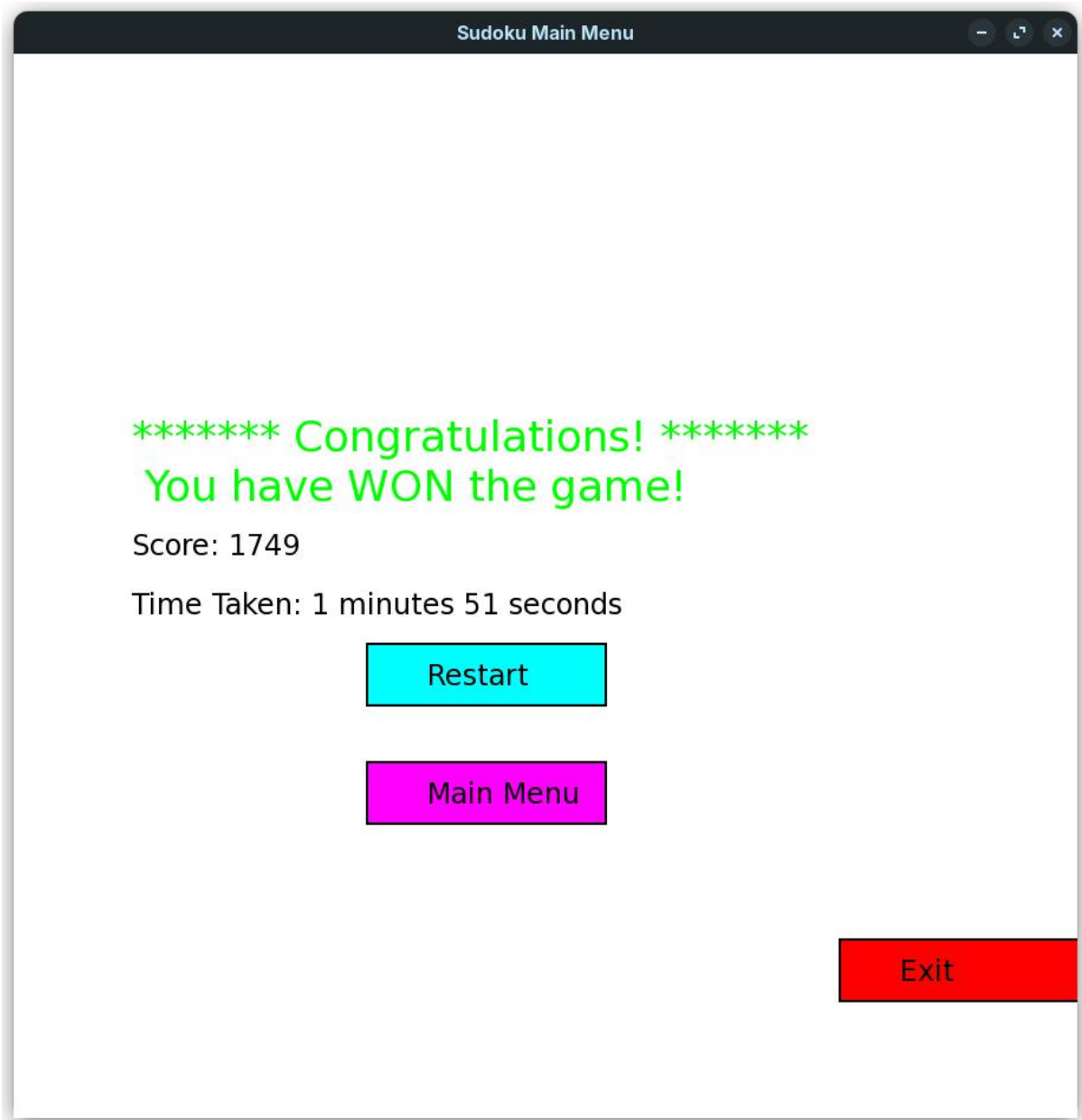


Figure 24: Image of Congratulation Screen

The user interface of the Sudoku Game Project is designed to provide an engaging and interactive experience for players. By following the detailed descriptions and sample inputs/outputs provided in this chapter, users can easily navigate through the game and enjoy playing Sudoku.

6. Challenges Faced

During the development of the Sudoku Game Project, several challenges were encountered. This section describes these challenges and the strategies employed to overcome them.

6.1 Handling User Input

Challenge: Handling user input efficiently was one of the primary challenges. The game needed to process mouse clicks and keyboard inputs to allow players to interact with the Sudoku grid, select cells, and enter numbers. Ensuring that the input handling was responsive and accurate was crucial for a seamless user experience.

Solution: To address this challenge, a robust input handling system was implemented using SFML. Mouse and keyboard events were processed within the main game loop, and appropriate actions were taken based on the type of input received. The code was structured to ensure that user inputs were accurately mapped to the corresponding cells in the Sudoku grid.

6.2 Generating Valid Sudoku Grids

Challenge: Generating valid Sudoku grids that meet the requirements of different variations (Traditional, Diagonal, Windoku) and difficulty levels was a complex task. The grids needed to be solvable, and each variation had specific constraints that had to be satisfied.

Solution: The solution involved implementing algorithms for each Sudoku variation and using backtracking techniques to fill the grids. Advanced techniques like X-Wing and Swordfish were also integrated to enhance the grid generation process. The algorithms were thoroughly tested to ensure that the generated grids were valid and met the desired difficulty levels.

6.3 Providing Hints

Challenge: Implementing a hint system that provides useful suggestions to players without compromising the challenge of the game was another significant challenge. The system needed to identify valid numbers for selected cells and limit the number of hints available.

Solution: A hint system was developed that uses the game logic to identify valid numbers for a selected cell. The number of hints was limited to maintain the challenge, and the system was integrated with the user interface to display hints to players.

6.4 Saving and Loading Game States

Challenge: Allowing players to save their progress and load saved game states was essential for providing a seamless gaming experience. This required efficiently managing the game state, including the Sudoku grid, lives, hints used, and elapsed time.

Solution: File handling functions were implemented to save the current game state to a file and load it when needed. The system ensured that all relevant data was accurately stored and retrieved, allowing players to resume their game from where they left off.

6.5 Performance Optimization

Challenge: Ensuring that the game runs smoothly without lag, even when handling large computations, was a critical requirement. The performance needed to be optimized for both grid generation and rendering.

Solution: Performance optimization techniques were employed, including efficient algorithms for grid generation and validation, and optimizing rendering in SFML. The game logic was carefully designed to minimize computational overhead and ensure a smooth user experience.

6.6 Ensuring Robustness and Reliability

Challenge: Ensuring the robustness and reliability of the application was essential to provide a high-quality gaming experience. This involved handling edge cases, preventing crashes, and ensuring the game logic was error-free.

Solution: Extensive testing was conducted, including unit testing, integration testing, and user acceptance testing. Test cases were designed to cover various scenarios and edge cases, and feedback from users was used to identify and fix any issues. Continuous improvement and optimization were integral parts of the development process.

7. Conclusion

The development of the Sudoku Game Project has been a comprehensive learning experience that encompassed various aspects of software development. Key learnings from this project include:

- **C++ Programming:** Enhanced understanding and proficiency in C++ programming, including advanced concepts such as data structures, and algorithms.
- **SFML Library:** Gained practical experience with the SFML (Simple and Fast Multimedia Library) framework, which is essential for creating graphical applications and handling user interactions.
- **Game Development:** Acquired knowledge of game development principles, including game logic, state management, and user interface design.
- **Problem-Solving:** Developed problem-solving skills by addressing challenges such as grid generation, input handling, and performance optimization.
- **File Handling:** Learned techniques for saving and loading game states, which is crucial for providing a seamless user experience.
- **Testing and Debugging:** Improved skills in testing and debugging, ensuring the robustness and reliability of the application.

The Sudoku Game Project provides a solid foundation for further enhancements and extensions. Potential future extensions include:

- **Multiplayer Mode:** Implementing a multiplayer mode that allows multiple players to compete or collaborate in solving Sudoku puzzles. This could include features such as real-time updates, leaderboards, and chat functionality.
- **Custom Puzzle Creation:** Enabling users to create and share their own Sudoku puzzles. This could involve a puzzle editor that allows users to design and save custom grids.
- **Advanced Analytics:** Providing detailed statistics and analytics on puzzle-solving techniques and performance. This could include tracking the number of puzzles solved, average completion time, and common errors.
- **Additional Variations:** Introducing more Sudoku variations, such as Jigsaw Sudoku, Killer Sudoku, and Samurai Sudoku, to offer diverse gameplay experiences.
- **Mobile Compatibility:** Adapting the application for mobile devices to reach a broader audience. This could involve optimizing the user interface for touchscreens and ensuring compatibility with different mobile operating systems.
- **Enhanced User Experience:** Adding features such as customizable themes, sound effects, and animations to enhance the overall user experience.
- **Machine Learning Integration:** Incorporating machine learning algorithms to provide intelligent hints and suggestions based on the player's solving patterns.

By addressing these potential extensions, the Sudoku Game Project can continue to evolve and provide an engaging and enjoyable experience for players of all skill levels.

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