Project Report

Sudoku Solver Visualizer

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Contents

Chapter 1

Introduction

1.1 Overview

The Sudoku solver game is a puzzle where players fill a 9x9 grid with numbers from 1 to 9, ensuring each row, column, and 3x3 sub grid contains all numbers without repetition. Players input numbers, validate their choices, and a solver algorithm finds the solution using backtracking. Hints may be provided, and players can request assistance. Once the grid is filled, the game displays the solution. Sudoku offers a challenging experience that requires logical thinking and problem-solving skills.

1.2 Motivation

The Sudoku solver game offers an engaging and enjoyable experience for players of all skill levels. It serves as a valuable tool to improve problem-solving abilities, learn Sudoku strategies, and develop logical reasoning skills. By observing the solver algorithm, players can enhance their problem-solving techniques and gain a sense of accomplishment. The game provides a platform to practice, learn, and experience the satisfaction of solving challenging Sudoku puzzles. Embrace the challenge, sharpen your mind, and enjoy the journey of Sudoku solving with the Sudoku solver game. [**?**].

1.3 Problem Definition

1.3.1 Problem Statement

When we chose this project, We were aware of facing some problems like:

- Input: The program should accept a 9x9 grid as input, representing a partially filled Sudoku puzzle. The input grid should contain numbers from 1 to 9, with 0 or empty cells denoting the blank spaces.
- Validation: The program should validate the input grid to ensure it follows the rules of Sudoku. Each row, column, and 3x3 subgrid should contain all numbers

from 1 to 9 without repetition. If the input grid violates the Sudoku rules, the program should indicate an invalid input.

- Solver Algorithm: The program should implement a backtracking algorithm to find a solution for the Sudoku puzzle. It should systematically explore different number combinations by placing valid numbers in empty cells and backtracking whenever an invalid configuration is reached.
- Solution Output: Upon successful solving of the Sudoku puzzle, the program should output the complete solution. The output should be a 9x9 grid where all empty cells are filled with valid numbers, satisfying the Sudoku rules.
- Efficiency: The solver program should efficiently find the solution to Sudoku puzzles of varying difficulty levels. It should minimize unnecessary computations and provide a timely response for both simple and complex puzzles.
- User Interface (optional): To enhance the user experience, the program may include a user interface where users can input the Sudoku puzzle, view the solution, and interact with the solver algorithm. The user interface can provide features such as hints, error checking, and the ability to enter puzzles step by step.

The goal of the Sudoku solver program is to provide an automated solution for Sudoku puzzles, enabling users to solve puzzles quickly and effortlessly. The program should deliver accurate and efficient results while maintaining the integrity of the Sudoku rules.

1.3.2 Complex Engineering Problem

1.4 Design Goals/Objectives

- Solve Sudoku puzzles accurately and efficiently.
- Ensure valid input and reject invalid or unsolvable puzzles.
- Provide an intuitive and interactive user interface.
- Optimize the solver algorithm for quick solving.
- Handle invalid or unsolvable puzzles with appropriate feedback.
- Support multiple difficulty levels for varied challenges.
- Track and display performance metrics for a competitive experience.

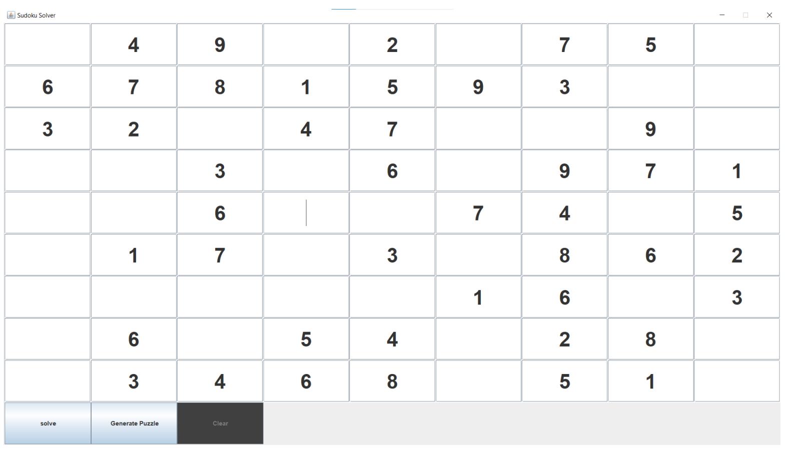
1.5 Application

The Sudoku-solving game has various applications that cater to puzzle enthusiasts, educational institutions, and anyone looking to improve their problem-solving skills. Here are some key applications of the Sudoku-solving game:

- Entertainment and Recreation: The Sudoku-solving game provides a fun and engaging activity for individuals of all ages. It offers a challenging puzzle-solving experience that can be enjoyed during leisure time or as a mental exercise to unwind and relax.
- Skill Development: The Sudoku solving game serves as a valuable tool for developing and honing problem-solving skills. It enhances logical reasoning, critical thinking, pattern recognition, and strategic planning abilities. Regularly engaging in Sudoku solving can lead to improved cognitive skills and mental agility.
- Educational Tool: The Sudoku solving game finds application in educational settings, such as schools and educational institutions. It can be used to introduce and teach concepts like logic, deductive reasoning, and number patterns. It encourages students to think analytically and boosts their problem-solving capabilities.
- Personal Growth: The Sudoku solving game promotes personal growth by fostering perseverance, patience, and the ability to handle challenges. It encourages individuals to overcome obstacles, learn from mistakes, and strive for continuous improvement. The game cultivates a growth mindset and a sense of accomplishment upon successfully solving puzzles.
- Brain Training: The Sudoku solving game is often used as a brain-training exercise to keep the mind sharp and active. Regular practice helps maintain mental acuity and memory retention. It offers a stimulating workout for the brain and can be part of a comprehensive brain-training regimen.
- The Sudoku solving game is widely available on various platforms, including mobile devices and online websites. Its accessibility allows users to engage in puzzle-solving anytime, anywhere, providing convenience and flexibility.
- Project Coordination and Management: AutoCAD's project management features allow the team to track and manage the progress of the design project. They can create schedules, set deadlines, and assign tasks to team members, ensuring efficient coordination and completion of the design tasks.

In summary, the Sudoku solving game has versatile applications, ranging from entertainment and skill development to educational use and personal growth. It offers an enjoyable and beneficial experience that challenges the mind, promotes problem-solving skills, and enhances cognitive abilities.

1.5.1 Output visualization



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

Figure 1.1: Visualizer

Table 1.1: Summary of the attributes touched by the mentioned projects

Name of the P Attributes	**Explain how to address**
P1: Depth of knowledge required	Familiarity with logical reasoning, number patterns, and problem-solving techniques is essential to effectively solve Sudoku puzzles.
P2: Range of conflicting requirements	Balancing efficiency and accuracy, while providing user-friendly features and maintaining adherence to Sudoku rules, presents a range of conflicting requirements in Sudoku solving.
P3: Depth of analysis required	The depth of analysis required for Sudoku solving involves employing advanced logical deduction techniques, including complex patterns and inter-dependencies, to uncover hidden relationships and make precise choices.
P4: Familiarity with issues	Developing familiarity with common issues in Sudoku solving, such as invalid input, unsolvable puzzles, and efficient algorithms, helps ensure accurate solutions and a smooth solving experience
P5: Extent of applicable codes	The applicable codes for Sudoku solving encompass algorithms for puzzle generation, validation, backtracking, and user interface implementation.
P6: Extent of stakeholder involvement and conflicting requirements	Balancing the input and expectations of diverse stakeholders while managing conflicting requirements to create a Sudoku solving solution that satisfies various user preferences and objectives.
P7: Interdependence	The successful solving of Sudoku puzzles relies on the interdependence between logical deduction, pattern recognition, and the ability to eliminate possibilities through iterative testing and backtracking.

Chapter 2

Design/Development/Implementation of the Project

2.1 Introduction

The Sudoku Solving project is a user-friendly application centred around a 9x9 grid panel and three key buttons: "Sudoku Generate," "Solve," and "Clear." It provides an intuitive interface for generating, solving, and clearing Sudoku puzzles. The "Sudoku Generate" button creates valid and solvable puzzles, displaying them on the grid panel. The "Solve" button employs efficient algorithms to determine the solution, updating the grid dynamically. The "Clear" button resets the grid for new challenges. The project prioritizes user experience and interface design, offering a sleek platform for Sudoku enthusiasts.

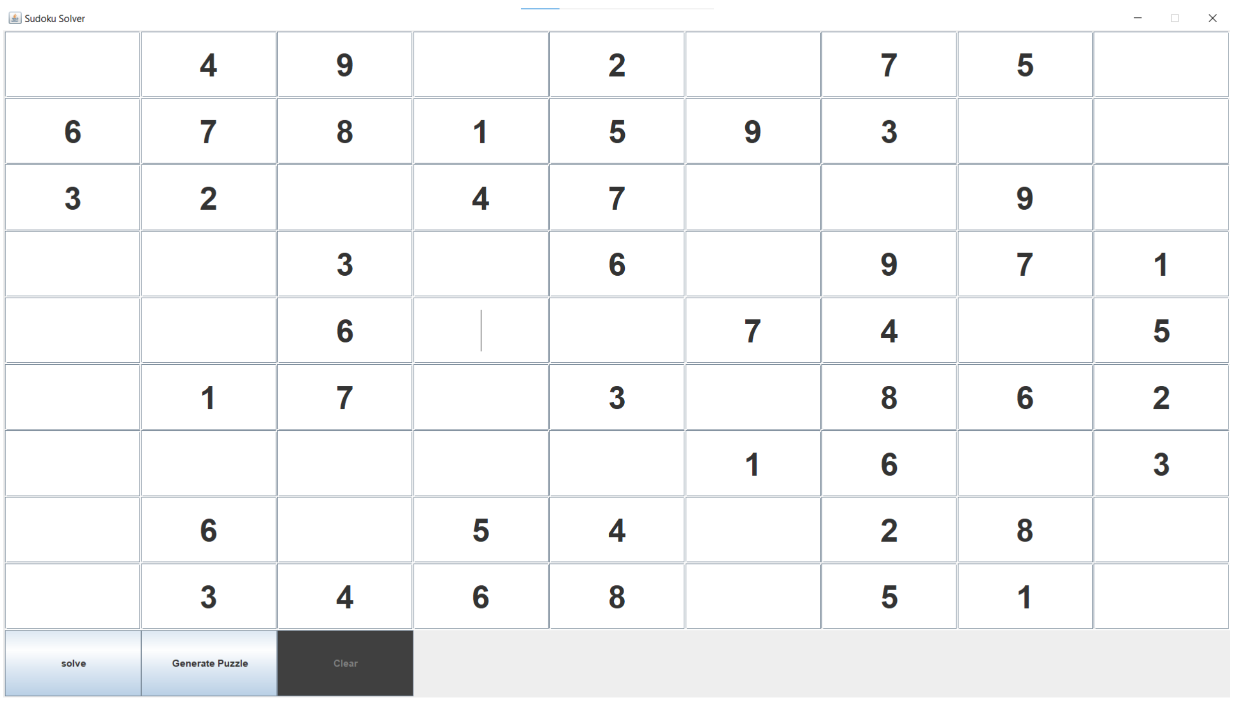
2.2 Project Details

The Sudoku Solving project is designed to provide a user-friendly interface for solving Sudoku puzzles. It utilizes a 9x9 grid panel and three buttons: "Sudoku Generate," "Solve," and "Clear." This document provides a detailed overview of the project, including key features, implementation details, and visualization techniques.

2.2.1 Key Features

- **Sudoku Generation:** The "Sudoku Generate" button generates a new Sudoku puzzle with a unique solution. It ensures that the puzzle adheres to the rules of Sudoku, such as having no repeating digits in rows, columns, or smaller 3x3 sub-grids.
- **Sudoku Solver:** The "Solve" button employs an efficient algorithm to solve the generated Sudoku puzzle. It uses a backtracking technique to explore possible solutions and finds the correct solution that satisfies all the Sudoku rules. The solver also identifies invalid or unsolvable puzzles, providing appropriate feedback to the user.

- **Clear Functionality:** The "Clear" button resets the Sudoku grid to its initial state, allowing the user to start a new puzzle or erase their progress on the current one. results in a clear and intuitive manner.



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

Figure 2.1: User Interface Of Sudoku solver

2.3 Implementation

The project employs a graphical user interface (GUI) that includes a 9x9 grid panel representing the Sudoku puzzle. Each cell in the grid can be populated with a digit from 1 to 9, or left empty for the user to fill. The interface is intuitive and user-friendly, with clearly labeled buttons and visual cues to guide the user's interactions.

2.3.1 User Interface:

The project employs a graphical user interface (GUI) that includes a 9x9 grid panel representing the Sudoku puzzle. Each cell in the grid can be populated with a digit from 1 to 9, or left empty for the user to fill. The interface is intuitive and user-friendly, with clearly labeled buttons and visual cues to guide the user's interactions.

2.3.2 Sudoku Generation Algorithm:

To generate a new Sudoku puzzle, the project employs an algorithm that ensures a unique solution. It starts with an empty grid and progressively fills cells while adhering to the Sudoku rules. The algorithm employs techniques like randomization and constraint satisfaction to create diverse puzzles.

- **Empty Grid Initialization:** The algorithm begins with an empty 9x9 Sudoku grid where all cells are initialized to be empty.
- **Randomized Cell Population:** To create a unique puzzle, the algorithm populates a random selection of cells in the grid. The number of initially filled cells can vary, depending on the desired difficulty level of the puzzle. For example, easier puzzles may have more initially filled cells, while harder ones have fewer.
- **Constraint Satisfaction** After populating a set of cells, the algorithm performs constraint satisfaction techniques to ensure that the puzzle remains solvable and adheres to Sudoku rules. It checks that no initial conflict exists between the pre-filled cells, ensuring that no digit violates the constraints within its row, column, or 3x3 sub-grid.
- **Backtracking Approach:** The algorithm then employs a backtracking strategy to complete the puzzle by filling the remaining empty cells. It iterates through each empty cell and attempts to place a valid digit (1 to 9) that does not violate any Sudoku rules. If a digit leads to a conflict, the algorithm backtracks and tries a different digit until a valid placement is found.
- **Solution Uniqueness:** Throughout the puzzle generation process, the algorithm ensures that the solution obtained is unique. After completing the puzzle, it verifies that there is only one possible solution by attempting to solve the generated puzzle using a Sudoku solver algorithm. If multiple solutions are found, the algorithm modifies the filled cells or backtracks to create a puzzle with a unique solution.

2.3.3 Sudoku Solving Algorithm:

The Sudoku-solving algorithm is responsible for finding the solution to a given Sudoku puzzle. It employs an efficient approach that systematically explores possible digit placements in empty cells while ensuring that all Sudoku rules are satisfied. Here are more details about the Sudoku-solving algorithm:

- **Backtracking:** The solving algorithm utilizes a backtracking technique, which is a recursive search strategy that explores all possible solutions by making informed guesses and backtracking when a conflict or inconsistency arises. This approach guarantees finding the correct solution by systematically exploring the solution space.
- **Empty Cell Selection** The algorithm starts by selecting an empty cell in the Sudoku grid to fill. It can follow various strategies for selecting the next cell, such as choosing the top-leftmost empty cell or selecting the cell with the fewest possibilities.
- **Digit Placement:** For the selected empty cell, the algorithm attempts to place a digit (1 to 9) that satisfies the Sudoku constraints. It checks if the chosen digit violates any rules within the cell's row, column, or 3x3 sub-grid. If a conflict arises, the algorithm backtracks and tries a different digit.
- **Recursive Exploration:** After placing a digit in the current cell, the algorithm recursively explores the next empty cell, repeating the digit placement process. This recursive exploration continues until all cells are filled, and a valid solution is found. If a conflict occurs in any step, the algorithm backtracks to the previous cell and tries a different digit until a solution is ultimately found.
- **olution Verification:** Once a solution is obtained, the algorithm verifies its correctness by ensuring that it satisfies all Sudoku constraints. It checks that no digit is repeated in any row, column, or 3x3 sub-grid. If the solution is invalid, the algorithm continues the backtracking process to find an alternative solution or reports that the puzzle is unsolvable.
- **Optimizations:** To improve efficiency, the solving algorithm can incorporate various optimizations. For example, it can use techniques like constraint propagation or constraint satisfaction to reduce the number of possibilities and narrow down potential digit placements. Additionally, the algorithm can employ strategies like "minimum remaining values" or "least-constraining value" heuristics to prioritize cells with the fewest possibilities, improving the search efficiency.

2.3.4 Visualization Techniques:

The project incorporates a time delay feature to showcase the solving process gradually. By introducing a pause between each step, the user can observe how the algorithm progresses through the puzzle. The time delay can be adjusted based on the desired speed of the animation, allowing the user to follow the solving process at their own pace.

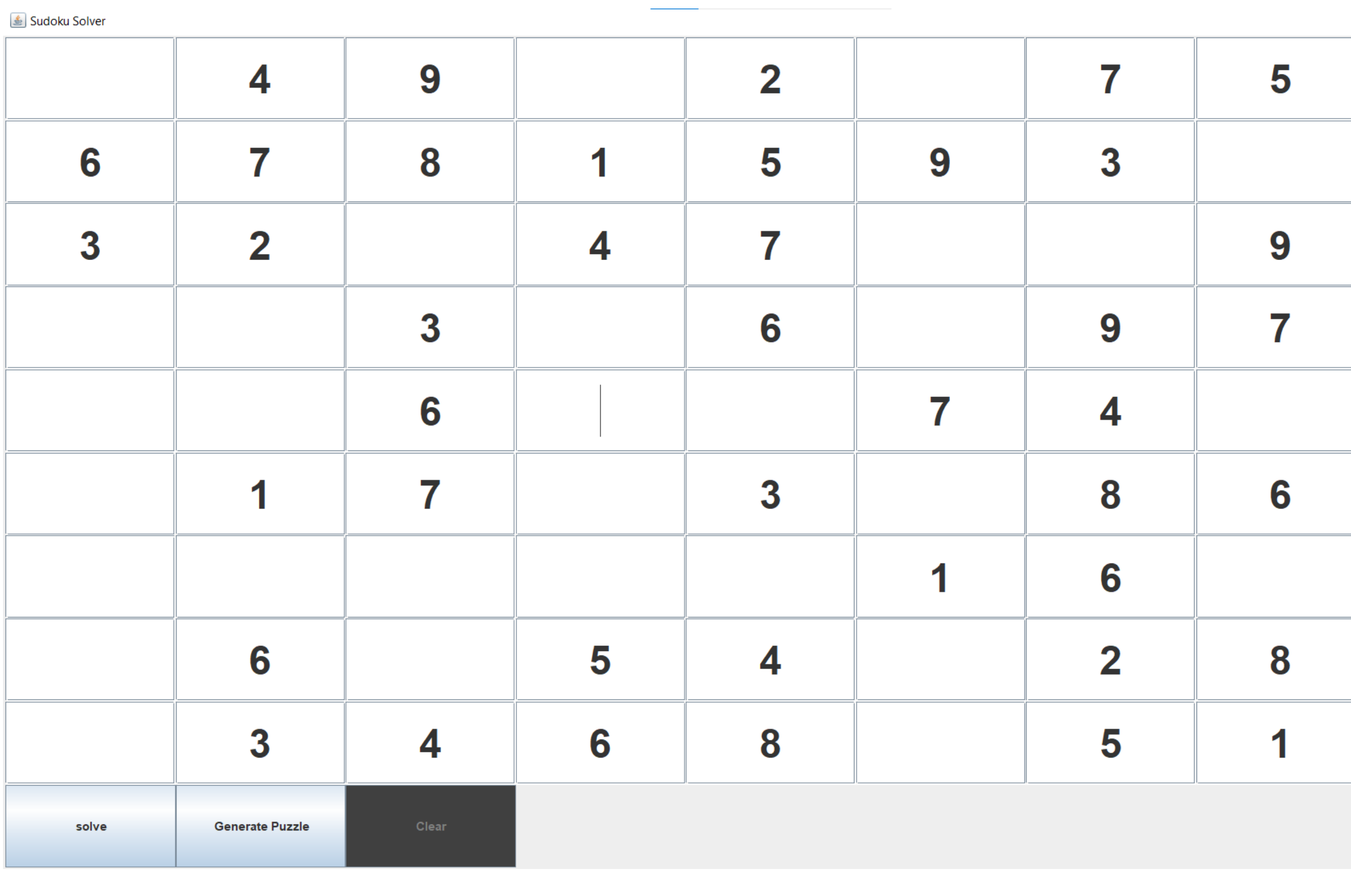
Tools and Libraries

- Programming Language: Java.
- Integrated Development Environment (IDE): visual St
- Visualization Libraries: Java Swing.
- User Interface (UI) Libraries or Frameworks: Java AWT, Java Swing,

2.3.5 Implementation Details (With Screenshots)

User Interaction:

The Sudoku Solving project offers a user-friendly interface for generating and solving Sudoku puzzles. Upon launching the application, a 9x9 grid panel is displayed, representing the Sudoku puzzle. The user can click the "Sudoku Generate" button to create a new puzzle, which is populated with a unique solution. Manual input is optional, allowing the user to enter digits into empty cells. By clicking the "Solve" button, the solving algorithm starts and gradually fills the cells using a backtracking approach. Time delay visualization and color highlighting enhance the user experience, showcasing the solving process step by step. Once a solution is found, the completed puzzle is displayed on the grid. The "Clear" button allows the user to reset the grid. The project provides an intuitive interface for users to interact with Sudoku puzzles, making it enjoyable and engaging.



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

Figure 2.2: User Interface / Buttons Of Visualizer

2.4 Algorithms

Algorithm is the prepossess to solve a problem.It is noting but a step by step procedure for the full program.Here is the main algorithm part for my project .

Algorithm 1: Sudoku Solving Algorithm

```
Input: Sudoku grid
Output: Boolean indicating if Sudoku is solved

/* Recursive function to solve the Sudoku puzzle                    */
/* Find the first empty location in the Sudoku grid                 */
/* If no empty location is found, the Sudoku is already
   solved                                                           */
/* Initialize row and column variables                              */
int row = 0; int col = 0; int[] a = FindEmptyLocation (row, col);
/* If there are no empty locations, Sudoku is already solved
   */
if a[0] == 0 then
    return true;
/* Get the position of the empty row and column                     */
row = a[1]; col = a[2];
/* Attempt to fill numbers from 1 to 9 into the empty
   location                                                         */
for int i = 1; i ≤ SIZE; i++ do
    /* Check if number i can be safely filled into the empty
       location                                                     */
    if NumberIsSafe (i, row, col) then
        /* Fill the number i into the empty location                */
        get [row][col] = i
        /* Recursive call to solve the Sudoku with the updated
           grid                                                     */
        if public boolean solveSudoku() () then
            return true
        /* Backtracking                                             */
        /* If the solution is wrong, reassign the value             */
        get [row][col] = 0
return false;
public boolean solveSudoku() ();
```

Algorithm 2: Find Empty Location in Sudoku Grid Algorithm

```
Input: Sudoku grid, row, col
Output: Array with flag, row, and column values
public int[] FindEmptyLocation((int row, int col))
int flag = 0; // Iterate through each cell in the Sudoku grid for (int i = 0; i <
  SIZE; i++)  for (int j = 0; j < SIZE; j++)  // Check if the cell is empty if (get
  [i][j] == 0)  // Assign the row and column values of the empty cell row = i; col
  = j; flag = 1;
// Create an array with flag, row, and column values int[] a = flag, row, col;
  return a;
// If no empty cell is found, return an array with flag = 0 and row = -1, col = -1
  int[] a = flag, -1, -1; return a;
// Example usage of the FindEmptyLocation function int row = 0; int col = 0;
  int[] result = FindEmptyLocation (row, col);
```

Algorithm 3: Check if Number is Safe to Place in Sudoku Grid Algorithm

```
Input: Sudoku grid, number n, row r, column c
Output: Boolean indicating if number n is safe to place at position (r, c)
public boolean NumberIsSafe((int n, int r, int c))
// Check if number n already exists in the same column for int i = 0; i < SIZE;
  i++ do
    if get [r][i] == n then
        return false
// Check if number n already exists in the same row for int i = 0; i < SIZE; i++
  do
    if get [i][c] == n then
        return false
// Check if number n already exists in the corresponding sub-matrix int
  row$_start = (r/3) * 3;$ int $col_start = (c/3) * 3;$
for int i = $row_start; i < row_start + 3; i++$ do
    for int j = $col_start; j < col_start + 3; j++$ do
        if get [i][j] == n then
            return false
    return true
    // Example usage of the NumberIsSafe function int number = 5; int row = 2;
      int col = 4; boolean isSafe = NumberIsSafe (number, row, col);
```

```
Algorithm 4: Sudoku Solving Algorithm
  Input: Sudoku grid
  Output: Boolean indicating if Sudoku is solved

1  solveSudoku()
   // Recursive function to solve the Sudoku puzzle
   // Find the first empty location in the Sudoku grid
   // If no empty location is found, the Sudoku is already
      solved
   // Initialize row and column variables
2  row ← 0 col ← 0 []a ← FindEmptyLocation(row, col)
   // If there are no empty locations, Sudoku is already solved
3  if a[0] == 0 then
4      return true
   // Get the position of the empty row and column
5  row ← a[1] col ← a[2]
   // Attempt to fill numbers from 1 to 9 into the empty
      location
6  for i ← 1toSIZE do
       // Check if number i can be safely filled into the empty
          location
7      if NumberIsSafe (i, row, col) then
           // Fill the number i into the empty location
8          get [row][col] ← i
           // Recursive call to solve the Sudoku with the updated
              grid
9          if solveSudoku () then
10             return true
           // Backtracking
           // If the solution is wrong, reassign the value
11         get [row][col] ← 0
12 return false
13 solveSudoku ()
```

Chapter 3

Performance Evaluation

3.1 Simulation Environment/ Simulation Procedure

The simulation environment was developed using Java programming language, specifically utilizing the Java Swing library for creating the graphical user interface (GUI). The environment provides a user-friendly interface for Sorting Algorithm Visualizer. The development environment used for this project includes:

- Java Development Kit (JDK) version 7 or higher
- Integrated Development Environment (IDE) such as Visual Studio code. this case, I have used Visual Studio code editor

Device

- **Brand**: Dell
- **Model Name**: Inspiron 15 3501
- **Screen Size**: 15.6 inches
- **Colour**: Silver
- **SSD**: 512 GB
- **CPU Model**: i5-1135G7
- **RAM Memory Installed Size**: 8 GB
- **Operating System**: Windows 10 Pro
- **Graphics Card Description**: NVIDIA GeForce MX330 with 2GB DDR5

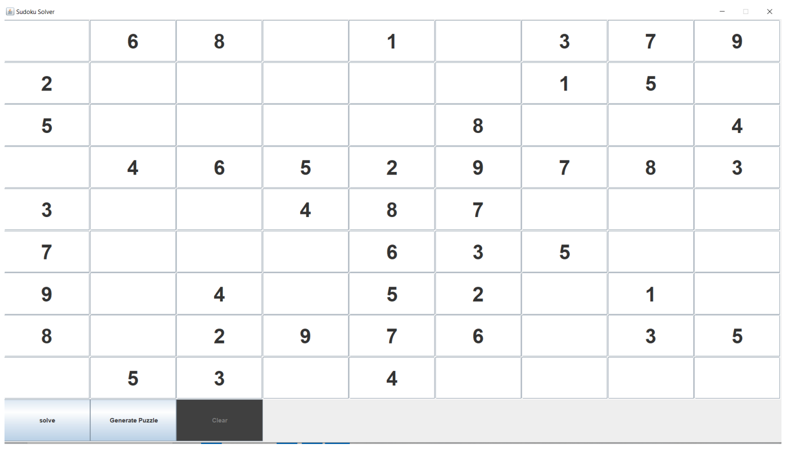
3.2 Results Analysis/Testing

The Sudoku Solving project aims to provide a user-friendly interface for generating and solving Sudoku puzzles. It utilizes a 9x9 grid panel and incorporates three main buttons: "Sudoku Generate," "Solve," and "Clear." The "Sudoku Generate" button generates a new Sudoku puzzle with a unique solution, offering users fresh challenges. The "Solve" button triggers the solving algorithm, visually displaying the step-by-step solving process on the grid. It employs time delay visualization to enhance the user experience. The "Clear" button allows users to reset the grid, providing a clean slate for new puzzles or starting over. Together, these buttons create an interactive environment for users to generate, solve, and engage with Sudoku puzzles..

3.2.1 Result_Case_1

Sudoku Generate Button:

This is the picture of the Sudoku Generating Button work



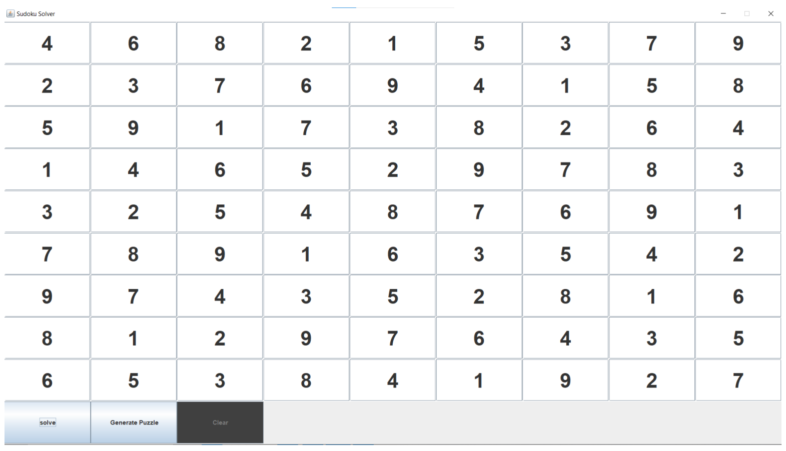
	6	8		1		3	7	9
2						1	5	
5					8			4
	4	6	5	2	9	7	8	3
3			4	8	7			
7				6	3	5		
9		4		5	2		1	
8		2	9	7	6		3	5
	5	3		4				

Figure 3.1: Generate Button

3.2.2 Result_Case_2

Sudoku solving Button:

This is the picture of the Sudoku-solving Button work



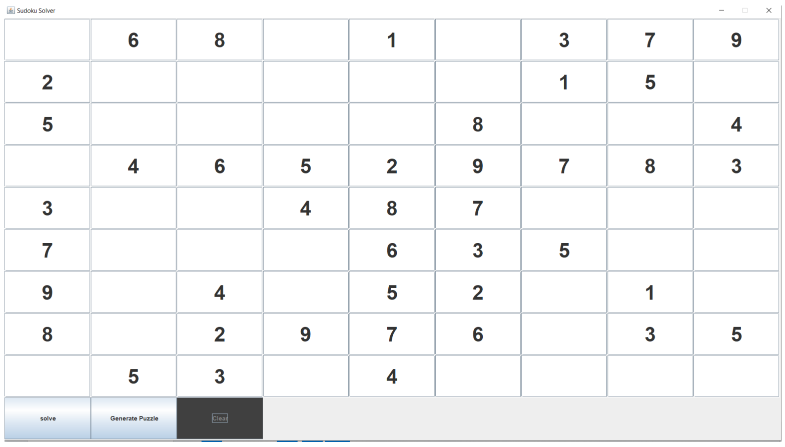
4	6	8	2	1	5	3	7	9
2	3	7	6	9	4	1	5	8
5	9	1	7	3	8	2	6	4
1	4	6	5	2	9	7	8	3
3	2	5	4	8	7	6	9	1
7	8	9	1	6	3	5	4	2
9	7	4	3	5	2	8	1	6
8	1	2	9	7	6	4	3	5
6	5	3	8	4	1	9	2	7

Figure 3.2: Marge Sort Visualization

3.2.3 Result_Case_3

Clear Button:

This is the picture of clear Button work



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

Figure 3.3: Selection Sort Visualization

3.3 Results Overall Discussion

The Sudoku Solving project offers a user-friendly interface for generating and solving Sudoku puzzles. With a 9x9 grid panel and three main buttons, namely "Sudoku Generate," "Solve," and "Clear," the project provides a comprehensive experience for Sudoku enthusiasts.

The "Sudoku Generate" button generates new puzzles, ensuring a unique solution each time. The Sudoku generation algorithm populates a random selection of cells in the grid, resulting in puzzles with varying levels of difficulty. This feature allows users to have a continuous supply of fresh challenges.

The "Solve" button triggers the Sudoku solving algorithm, which employs a backtracking approach to fill the empty cells systematically. The solving process is visually displayed on the grid, with a time delay feature and color highlighting for enhanced visualization. Users can observe each step of the algorithm and gain insights into the solving process.

The "Clear" button provides a convenient option for users to reset the grid to its initial state. This feature allows users to start fresh with a new puzzle or erase their progress on the current one, ensuring flexibility and convenience.

By combining these functionalities, the Sudoku Solving project offers an interactive and engaging experience. Users can generate new puzzles, solve them with the assistance of the algorithm, and reset the grid as needed. The project provides a user-friendly interface, making it accessible to Sudoku enthusiasts of all skill levels.

3.3.1 Complex Engineering Problem Discussion

Several complex engineering problems across different categories.

1. **Depth of Knowledge Required:** The Sudoku Solving project requires a depth of knowledge in various areas. A strong understanding of Sudoku rules and logic is necessary, along with proficiency in algorithmic problem solving to implement the Sudoku solving algorithm effectively. Competence in a programming language, such as Python, Java, C++, or JavaScript, is essential for developing the project. Familiarity with data structures and grid representation is required to manipulate and store Sudoku puzzles. Basic knowledge of user interface design principles and development frameworks like HTML, CSS, JavaScript, Swing, or JavaFX is necessary to create an intuitive user interface. Understanding how to incorporate time delay and visualization techniques to demonstrate the solving process is important. Proficiency in testing and debugging is crucial for ensuring the correctness and reliability of the project. This broad range of knowledge ensures the successful development and implementation of the Sudoku Solving project.

2. **Range of Conflicting Requirements:** The Sudoku Solving project encompasses a range of conflicting requirements that must be carefully addressed. On one hand, the project aims to generate Sudoku puzzles that are challenging and diverse, requiring a sophisticated algorithm for puzzle generation. On the other

hand, the solving algorithm must be efficient and capable of solving puzzles in a reasonable amount of time. The user interface should be intuitive and visually appealing while also providing clear feedback and visualizations of the solving process. Balancing these conflicting requirements requires careful consideration, such as finding the right balance between generating complex puzzles and ensuring solvability, optimizing the solving algorithm for speed without sacrificing accuracy, and designing a visually appealing and informative interface. Striking the right balance is crucial to create a Sudoku Solving project that offers enjoyable and challenging puzzles while providing a seamless user experience.

3. **Depth of Analysis Required:** The Sudoku Solving project requires a depth of analysis in various areas. This includes analyzing the puzzle generation algorithm to ensure unique solutions and varying difficulty levels, assessing the correctness and efficiency of the solving algorithm, evaluating user interaction and interface usability, conducting performance analysis to optimize speed and responsiveness, analyzing error handling and validation mechanisms, assessing cross-platform compatibility, and evaluating overall usability and user experience. Thorough analysis in these areas is essential to refine and improve the project, ensuring it meets high standards of puzzle generation, solving accuracy, user interaction, performance, error handling, compatibility, and user satisfaction.

4. **Extent of Applicable Codes:** The Sudoku Solving project involves the implementation of various codes. This includes code for puzzle generation to create Sudoku puzzles of different difficulty levels, code for the solving algorithm to find solutions using backtracking or other search algorithms, code for the user interface to provide an interactive grid, buttons, and visual feedback, code for validation and error handling to ensure the entered puzzles are valid and solvable, code for time delay and visualization techniques to demonstrate the solving process gradually, code for performance optimization to enhance efficiency, and code for testing to validate the implemented functionalities. The extent of applicable codes for the project spans puzzle generation, solving, user interface, validation, time delay, visualization, performance optimization, and testing, all of which contribute to the successful implementation and functionality of the Sudoku Solving project.

Chapter 4

Conclusion

4.1 Discussion

The Sudoku Solving project utilizes a user-friendly interface with three buttons: "Sudoku Generate," "Solve," and "Clear." The "Sudoku Generate" button generates a unique Sudoku puzzle, while the "Solve" button applies an algorithm to solve the puzzle step-by-step, visually displaying the progress. The "Clear" button resets the grid. Overall, the project offers an enjoyable Sudoku-solving experience with puzzle generation, solving algorithm implementation, and user interaction.

4.2 Limitations

limitations include:

- **Complexity of Puzzle Generation:** Generating Sudoku puzzles with unique solutions can be a computationally intensive task, especially when aiming to provide puzzles of varying difficulty levels. As a result, the puzzle generation process may take longer for more challenging puzzles, which can impact user experience.

- **Inability to Solve Invalid Puzzles:** The solving algorithm assumes that the input puzzle is a valid Sudoku configuration. If an invalid or unsolvable puzzle is provided, the algorithm may run indefinitely or produce incorrect results. It is important to ensure that the project includes appropriate error handling and validation mechanisms to prevent such scenarios.

- **Lack of Advanced Solving Techniques:** The The current implementation of the solving algorithm relies solely on backtracking. While backtracking is an effective method for solving Sudoku puzzles, it may not utilize more advanced solving techniques like constraint propagation or advanced heuristics. Incorporating additional solving techniques could enhance the algorithm's efficiency and provide more optimized solutions.

4.3 Scope of Future Work

Scope of Future Work for the Sudoku Solving Project:

- **Advanced Solving Techniques:** The project can be expanded to incorporate more advanced solving techniques, such as constraint propagation, hidden singles, naked pairs, and other advanced strategies used in Sudoku solving. Implementing these techniques would enhance the solving algorithm's efficiency and provide faster and more optimized solutions.
- **Puzzle Validation and Error Detection:** Enhancing the project to include puzzle validation and error detection mechanisms would help identify invalid or unsolvable puzzles at the input stage. This would prevent the solving algorithm from running indefinitely on incorrect puzzles and provide users with immediate feedback on the validity of their inputs.
- **Mobile and Cross-Platform Compatibility:** Adapting the project for mobile devices and ensuring cross-platform compatibility would expand its reach and make it accessible to a wider audience. This could involve developing a responsive user interface or creating dedicated mobile applications for iOS and Android platforms.
- **Additional Grid Sizes and Variations:** Extending the project to support different grid sizes and variations of Sudoku, such as 4x4, 16x16, or irregularly shaped grids, would provide users with more puzzle options and challenges. Implementing additional grid sizes would require modifying the solving algorithm and adapting the user interface to accommodate the changes.
- **Multiplayer and Online Challenges:** Implementing multiplayer functionality would enable users to compete against each other in solving Sudoku puzzles. This could involve real-time puzzle synchronization, leaderboards, and timed challenges, adding a social and competitive aspect to the project.

4.4 References

Please Visit the Following Link For More Information:

- https://youtu.be/tRj4VlVTat8
- https://youtu.be/qH9mWpYMtYU