PROJECT REPORT

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Project Title - Sudoku Solver

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Introduction

Sudoku is a popular logic-based number puzzle that challenges players to fill a 9x9 grid with digits such that each column, each row, and each of the nine 3x3 subgrids contain all of the digits from 1 to 9. The Sudoku Solver and Visualizer project is a Java-based application designed to provide an interactive platform for solving and visualizing Sudoku puzzles. This report provides a comprehensive overview of the project, detailing its objectives, features, implementation, user interface design, challenges encountered, and future enhancements.

Project Objectives

The primary objectives of the Sudoku Solver and Visualizer project are:

1. **Develop an Interactive User Interface**: Create a user-friendly GUI that allows users to input and solve Sudoku puzzles interactively.
2. **Implement an Efficient Solving Algorithm**: Develop a robust algorithm capable of solving Sudoku puzzles in a timely manner.
3. **Enhance User Experience**: Provide features such as manual mode, real-time solving visualization, and error highlighting to improve user engagement.
4. **Ensure Code Quality and Maintainability**: Write clean, well-documented code to ensure the project can be easily understood and extended in the future.

Project Features

The Sudoku Solver and Visualizer includes the following key features:

1. **Interactive Grid Interface**: A 9x9 grid where users can input Sudoku numbers. Each cell in the grid is a `JTextField` that allows for easy number entry.
2. **Automatic Solver**: An algorithm that automatically solves the Sudoku puzzle, with the solving process visualized in real-time.
3. **Manual Mode**: Allows users to manually input numbers into the grid, with real-time validation to ensure entries are valid according to Sudoku rules.
4. **Error Highlighting**: Highlights cells with invalid entries in red to alert the user of mistakes.
5. **Button Controls**: Includes buttons for loading a puzzle, solving the puzzle automatically, clearing the grid, toggling manual mode, and entering numbers 1-9.
6. **Professional Color Scheme**: Uses a professional and visually appealing color scheme to enhance the user experience.

Implementation Details

Grid Layout

The grid layout is implemented using a 9x9 `JPanel` with a `GridLayout`. Each cell in the grid is a `JTextField` that allows users to enter numbers. The cells are bordered to clearly define the 3x3 subgrids, enhancing the visual appeal and making it easier for users to follow the Sudoku rules.

```
java Copy
code
JPanel gridPanel = new JPanel();
gridPanel.setLayout(new GridLayout(SIZE, SIZE));
gridPanel.setBackground(Color.WHITE);
 for (int row = 0; row < SIZE; row++) {
for (int col = 0; col < SIZE; col++) {          cells[row][col] = new
JTextField();
        cells[row][col].setHorizontalAlignment(JTextField.CENTER);
cells[row][col].setFont(new Font("Arial", Font.BOLD, 20));
cells[row][col].setForeground(Color.DARK_GRAY);
        cells[row][col].addActionListener(new CellClickListener(row, col));
        // Set borders for 3x3 subgrids
        Border border = BorderFactory.createMatteBorder(


            row % 3 == 0 ? 2 : 1,
col % 3 == 0 ? 2 : 1,


      row % 3 == 2 ? 2 : 1,
col % 3 == 2 ? 2 : 1,
            Color.LIGHT_GRAY
        );
        cells[row][col].setBorder(border);
cells[row][col].setBackground(Color.WHITE);


        gridPanel.add(cells[row][col]);
    } } add(gridPanel, BorderLayout.CENTER);
```

Algorithm

The solving algorithm is a backtracking algorithm that recursively attempts to place numbers 1-9 in empty cells, ensuring that each placement adheres to Sudoku rules. If a placement is valid, the algorithm proceeds to the next cell. If a placement leads to a dead end, the algorithm backtracks and tries the next number.

```
java Copy
code
private boolean solve() {      int[]
empty = findEmptyCell();      if
(empty == null) {          return
true;      }
    int row = empty[0];
int col = empty[1];
     for (int num = 1; num <= 9; num++)
{          if (isValid(row, col, num)) {
board[row][col] = num;             rows[row].add(num);
cols[col].add(num);
```

```
            subgrids[(row / 3) * 3 + col / 3].add(num);
cells[row][col].setText(String.valueOf(num));


            try {
                Thread.sleep(5); // Delay of 5 milliseconds
} catch (InterruptedException e) {
                e.printStackTrace();
            }


            if (solve()) {
return true;
            }


            // Undo move             board[row][col] = 0;
rows[row].remove(num);             cols[col].remove(num);
subgrids[(row / 3) * 3 + col / 3].remove(num);
cells[row][col].setText("");
        }
}      return false; }
```

User Interaction

User interaction is handled through action listeners attached to each cell and button. In manual mode, users can click on cells to select them and input numbers using a button panel. `java Copy`

```
code
private class CellClickListener implements ActionListener {
private final int row, col;


    public CellClickListener(int row, int col) {
this.row = row;         this.col = col;
    }


    @Override
    public void actionPerformed(ActionEvent e) {
if (manualMode) {
            if (selectedCell != null) {
selectedCell.setBackground(Color.WHITE);
            }              selectedCell = cells[row][col];
selectedCell.setBackground(Color.LIGHT_GRAY);
        }
    }
}
```

Color Scheme

The application uses a professional color scheme with white backgrounds for cells and panels, light gray for pre-filled cells, and color-coded buttons for different actions. This scheme ensures the interface is visually appealing and easy to navigate.

`java Copy`

```
code
loadButton.setBackground(new Color(173, 216, 230)); // Light blue background
solveButton.setBackground(new Color(144, 238, 144)); // Light green background
clearButton.setBackground(new Color(255, 182, 193)); // Light pink background
manualModeButton.setBackground(new Color(255, 255, 204)); // Light yellow background
```

Code Snippets

Grid Initialization

The following code snippet initializes the 9x9 grid of cells, setting the appropriate borders and action listeners for each cell.

```
java Copy
code
JPanel gridPanel = new JPanel();
gridPanel.setLayout(new GridLayout(SIZE, SIZE));
gridPanel.setBackground(Color.WHITE);
 for (int row = 0; row < SIZE; row++) {
for (int col = 0; col < SIZE; col++) {          cells[row][col] = new
JTextField();
        cells[row][col].setHorizontalAlignment(JTextField.CENTER);
cells[row][col].setFont(new Font("Arial", Font.BOLD, 20));
cells[row][col].setForeground(Color.DARK_GRAY);
        cells[row][col].addActionListener(new CellClickListener(row, col));
        // Set borders for 3x3 subgrids
        Border border = BorderFactory.createMatteBorder(             row % 3
== 0 ? 2 : 1,             col % 3 == 0 ? 2 : 1,             row % 3 == 2 ? 2 :
1,             col % 3 == 2 ? 2 : 1,
            Color.LIGHT_GRAY
        );
        cells[row][col].setBorder(border);
cells[row][col].setBackground(Color.WHITE);


        gridPanel.add(cells[row][col]);
    } } add(gridPanel, BorderLayout.CENTER);
```

Solving Algorithm

The solving algorithm uses a backtracking approach, recursively attempting to place numbers in the grid and backtracking if a placement leads to a dead end.

```
java Copy
code
private boolean solve() {      int[]
empty = findEmptyCell();      if
(empty == null) {          return
true;      }
    int row = empty[0];
int col = empty[1];


    for (int num = 1; num <= 9; num++) {
if (isValid(row, col, num))
{               board[row][col] = num;
rows[row].add(num);
cols[col].add(num);
            subgrids[(row / 3) * 3 + col / 3].add(num);
cells[row][col].setText(String.valueOf(num));


            try {
                Thread.sleep(5); // Delay of 5 milliseconds
} catch (InterruptedException e) {
                e.printStackTrace();
}
             if (solve()) {
return true;
            }


            // Undo move             board[row][col] = 0;
rows[row].remove(num);             cols[col].remove(num);
            subgrids[(row / 3) * 3 + col / 3].remove(num);
cells[row][col].setText("");
        }
}      return false; }
```

Manual Mode

Manual mode allows users to select cells and input numbers using a button panel. The selected cell is highlighted to provide visual feedback.

```
java Copy
code
private class CellClickListener implements ActionListener {
private final int row, col;


    public CellClickListener(int row, int col) {
this.row = row;         this.col = col;
    }


    @Override
    public void actionPerformed(ActionEvent e) {
if (manualMode) {             if (selectedCell
!= null) {
selectedCell.setBackground(Color.WHITE);
            }              selectedCell =
cells[row][col];
            selectedCell.setBackground(Color.LIGHT_GRAY);
        }
    }  }
```

User Interface Design

The user interface is designed to be intuitive and visually appealing. The main Sudoku grid is centrally placed, with a button panel on the right side for easy access to controls.

Grid Panel

The grid panel consists of a 9x9 grid of `JTextField` cells. Each cell is bordered to clearly define the 3x3 subgrids, and the cells are color-coded to distinguish between pre-filled and user-input values.

Button Panel

The button panel includes buttons for loading a puzzle, solving the puzzle automatically, clearing the grid, toggling manual mode, and entering numbers 1-9. The buttons are color-coded for easy identification.

```
java Copy
code
JPanel buttonPanel = new JPanel(); buttonPanel.setLayout(new
GridLayout(4, 1));

loadButton = new JButton("Load Puzzle");
loadButton.setBackground(new Color(173, 216, 230)); // Light blue background
loadButton.addActionListener(new LoadButtonListener()); buttonPanel.add(loadButton);

solveButton = new JButton("Automatic Solve");
solveButton.setBackground(new Color(144, 238, 144)); // Light green background
solveButton.addActionListener(new SolveButtonListener());
buttonPanel.add(solveButton);

clearButton = new JButton("Clear");
clearButton.setBackground(new Color(255, 182, 193)); // Light pink background
clearButton.addActionListener(new ClearButtonListener()); buttonPanel.add(clearButton);

manualModeButton = new JButton("Manual Mode");
manualModeButton.setBackground(new Color(255, 255, 204)); // Light yellow
background
manualModeButton.addActionListener(new ManualModeButtonListener());
buttonPanel.add(manualModeButton);

add(buttonPanel, BorderLayout.EAST);
```

Challenges and Solutions

Challenge 1: Implementing the Solving Algorithm

One of the primary

4o uyerfgjhvbueghvbnvbvfugevbdnvbxbvhjdgfvuyreyhdnbvzxcvbdfhgjkelrgiowqgpq;;q ChatGPT It seems like there was an unintended input. Let's continue with the project report.

Challenges and Solutions

Challenge 1: Implementing the Solving Algorithm

Problem: Developing an efficient algorithm to solve Sudoku puzzles automatically and in realtime. **Solution:** Implemented a backtracking algorithm, which systematically tries different number placements and backtracks when a placement leads to an invalid state. This ensures the solver is both accurate and efficient.

Challenge 2: User Interface Design

Problem: Creating an intuitive and visually appealing user interface that enhances user experience. **Solution:** Designed a clear and organized grid layout with color-coded cells and buttons. Emphasized usability by ensuring that buttons are easily distinguishable and the grid is easy to interact with.

Challenge 3: Error Highlighting

Problem: Providing real-time feedback to users when they make an invalid move. **Solution:** Implemented error highlighting, which marks cells with invalid entries in red. This immediate visual feedback helps users quickly identify and correct mistakes.

Challenge 4: Ensuring Code Quality

Problem: Maintaining high code quality and readability for future maintenance and enhancements. **Solution:** Adhered to best coding practices, including proper variable naming, code documentation, and modular design. This ensures that the code is easy to understand and extend.

Testing and Validation

Testing and validation are crucial to ensure the Sudoku Solver and Visualizer functions correctly and provides a seamless user experience. The following testing methodologies were employed:

Unit Testing

- **Grid Initialization:** Verified that the 9x9 grid initializes correctly with all cells set to default states.

- **Solving Algorithm:** Tested the solving algorithm with a variety of Sudoku puzzles, including easy, medium, and hard difficulties, to ensure it solves puzzles accurately and efficiently.
- **Manual Mode:** Tested manual mode to ensure users can input numbers, and errors are highlighted correctly.

Integration Testing

- **User Interface:** Ensured that all UI components, including buttons and the grid, function correctly together. Verified that user inputs are accurately reflected in the grid and that the solving process is visualized in real-time.
- **Error Handling:** Tested error handling by inputting invalid numbers and ensuring that the application responds appropriately by highlighting errors and providing feedback.

User Testing

- **Feedback Collection:** Collected feedback from users to identify areas for improvement in the user interface and functionality.
- **Usability Testing:** Conducted usability testing to ensure the application is intuitive and easy to use. Made adjustments based on user feedback to enhance the overall experience.

Conclusion

The Sudoku Solver and Visualizer project successfully achieves its objectives of providing an interactive platform for solving and visualizing Sudoku puzzles. The application features a userfriendly interface, an efficient solving algorithm, and various enhancements to improve user experience. Through rigorous testing and validation, the application is ensured to function correctly and provide a seamless experience for users.

Future Enhancements

While the current implementation of the Sudoku Solver and Visualizer is robust and functional, there are several potential enhancements that could further improve the application:

1. Enhanced Visualization

- **Step-by-Step Solving:** Implement a step-by-step solving feature that allows users to see each step of the solving process in detail.
- **Animation:** Add animations to make the solving process more visually engaging.

2. Additional Features

- **Puzzle Generator:** Implement a puzzle generator that can create new Sudoku puzzles of varying difficulties.
- **Hint System:** Add a hint system that provides users with hints when they are stuck, without solving the entire puzzle.

3. User Interface Improvements

- **Responsive Design:** Make the user interface responsive to different screen sizes and resolutions.
- **Customization Options:** Allow users to customize the color scheme and appearance of the grid and buttons.

4. Performance Optimization

- **Algorithm Optimization:** Optimize the solving algorithm for better performance with larger and more complex puzzles.
- **Resource Management:** Improve resource management to ensure the application runs smoothly on different devices.

By implementing these enhancements, the Sudoku Solver and Visualizer can continue to evolve and provide an even better experience for users.

This detailed project report covers the various aspects of the Sudoku Solver and Visualizer project, including its objectives, features, implementation details, challenges, testing, and future enhancements. If you need more specific sections or additional details, please let me know!