Project Report

Project Title: AI-Enhanced Sudoku
Submitted By: 21i-2957 Muhammad Wajih Hyder, 21k-3379 Abdul Ali Ahmed
Course: AI Lab
Instructor: Abdullah Yaqoob
Submission Date: 11th May 2025

1. **Executive Summary**
    a. Project Overview:
        i. This project focuses on developing an AI-enhanced Sudoku game that combines traditional Sudoku with AI-driven features. The game uses Reinforcement Learning (RL) for difficulty adjustment based on player performance and a basic backtracking algorithm for solving puzzles. It offers players a dynamic experience with hints, freezing cells, and adaptive puzzle difficulty.
2. **Introduction**
    a. Background:
        i. Sudoku is a classic puzzle game involving a 9x9 grid where players must fill each cell with digits from 1 to 9 without repeating in any row, column, or 3x3 sub-grid. This project enhances the conventional Sudoku game by incorporating AI for puzzle generation, solving, and adaptive gameplay.
    b. Objectives of the Project:
        i. Develop an AI model to generate and solve Sudoku puzzles.
        ii. Implement an adaptive difficulty system using Reinforcement Learning.
        iii. Allow players to interact with the puzzle using hints and cell-freezing mechanics.

3. **Game Description**
    a. Original Game Rules:
        i. Sudoku is a number puzzle where players must fill a 9x9 grid with numbers 1 to 9 without any repetition in rows, columns, or 3x3 boxes.
    b. Innovations and Modifications:
        i. Reinforcement Learning-based difficulty adjustment.
        ii. Interactive gameplay with hints, freezing cells, and a shifting mechanic for added challenge.

4. **AI Approach and Methodology**
    a. AI Techniques Used:
        i. Reinforcement Learning (Q-learning) for adaptive difficulty.
        ii. Backtracking algorithm for puzzle solving.
    b. Algorithm and Heuristic Design:
        i. RLAgent uses Q-learning to select difficulty based on player performance (speed and accuracy).
        ii. Backtracking is used for puzzle solving, ensuring a valid puzzle structure.
    c. AI Performance Evaluation:
        i. The RL agent adapts difficulty based on player mistakes and time taken.
        ii. Puzzle-solving algorithm has a near-instantaneous solution generation time.

5. **Game Mechanics and Rules**
    a. Modified Game Rules:
        i. Hints: Players can reveal the correct number in an empty cell.
        ii. Freeze Cells: Players can freeze certain cells, making them unchangeable.
        iii. Shift Mechanic: Every 5th correct move will trigger a cell-shifting event, rearranging some cells.
    b. Turn-based Mechanics:
        i. Players interact with the game using keyboard and mouse inputs.
        ii. The game continuously updates, providing real-time feedback.
    c. Winning Conditions:
        i. The player wins when the grid is correctly filled without any mistakes.

6. **Implementation and Development**
    a. Development Process:
        i. The game was developed using Python and the Pygame library.
        ii. The RL agent was designed using basic Q-learning principles, adjusting difficulty based on player performance.
    b. Programming Languages and Tools:
        i. Programming Language: Python
        ii. Libraries: Pygame, time, random
    c. Challenges Encountered:
        i. Balancing difficulty using Reinforcement Learning.

ii. Ensuring puzzle validity during generation.
iii. Shifting the cells and maintaining the solution

7. **Team Contributions**
    a. Wajih Hyder:
        i. Game UI(Board and Stats)
        ii. Shifting cells
        iii. Power ups(Freeze and Hints)
    b. Ali Ahmed
        i. Game logic
        ii. Rl algorithm
        iii. Solver and generator
8. **Results and Discussion**
    a. AI Performance:
        i. The RL agent adjusted difficulty effectively, making the game more challenging for experienced players.
        ii. Puzzle generation and solution were instantaneous.

9. **References**
    a. Pygame Documentation: https://www.pygame.org/docs/
    b. RL Q-Learning Guide: (Provide other references used)