What is a Sudoku?

Sudoku is a logic-based combinatorial number-placement puzzle. The objective is to fill a 9x9 grid with digits so that each column, each row, and each of the nine 3x3 subgrids (also called ”boxes”, ”regions”, or ”blocks”) contain all of the digits from 1 to 9.

> *Sudoku is a game of pure logic, where you win by eliminating all the possibilities until only one answer remains.*
> *— Howard Grans...*

Sudoku puzzles have an interesting history. While the modern version of Sudoku originated in Japan in the 1980s, similar number-placement puzzles have been around for centuries. The game gained worldwide popularity in the early 2000s.

Why Sudoku?

- **Motivation:** We aim to enhance Sudoku puzzle-solving efficiency, particularly for larger grids, by developing innovative methods. Our goal is to provide practical tools for enthusiasts and researchers while advancing algorithmic understanding.
- **Challenge:** Larger Sudoku grids pose increased complexity, surpassing the capabilities of standard methods. Efficient solutions are needed to address this challenge.
- **Solution:** Brute force methods, effective for smaller puzzles, become impractical for larger grids. Our focus is on developing optimized strategies that balance time and space efficiency.

Algorithms used in the project

Backtracking Search

Backtracking is a systematic approach to solving problems by exploring potential solutions incrementally and backtracking when a dead-end or contradiction is encountered.

Backtracking with heuristic approach

We're shifting to a heuristic-driven backtracking approach for Sudoku solving. Traditional backtracking struggles with larger grids. By integrating heuristics, we aim to guide the search efficiently, handling larger grids effectively. This approach offers a smarter and more optimized Sudoku-solving method.

algorithms used in the project

simulated annealing

Simulated annealing, adapted for Sudoku solving, is a probabilistic optimization algorithm that draws inspiration from the physical annealing process. It starts with an initial Sudoku configuration and iteratively explores neighboring solutions, allowing occasional suboptimal moves to prevent being trapped in local minima. The algorithm employs a temperature parameter, gradually decreasing over time, controlling the acceptance of less favorable solutions. This stochastic element introduces adaptability, fostering exploration of the puzzle's solution space.

Table

Algorithm	**Puzzle**	**Time Complexity**
Backtracking	NO	$O(N!)$
Heuristic Approach	NO	$O(N^{2N})$
Simulated Annealing	YES	$O(N^2 + I \cdot (E + N^2))$

Table: Time Complexities of Sudoku Solving Algorithms

What can be improved?

- **Optimized Neighbor Selection**: Explore different strategies for selecting neighboring states more efficiently. This could involve implementing smarter algorithms for generating neighboring states or refining the swapping mechanism to improve exploration of the solution space.
- **Fine-Tuning Parameters**: Experiment with different values for parameters such as initial temperature, cooling rate, and maximum iterations to find optimal settings for the simulated annealing algorithm. Fine-tuning these parameters can improve convergence speed and solution quality.