Artificial Intelligence

Assignment 2:
CSP Sudoku Solver

Under the supervision of:

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CSP Sudoku Solver

Sudoku is a popular **puzzle game** that has captured the hearts and minds of puzzle enthusiasts around the globe. Its **simple rules** and **challenging gameplay** make it a favorite pastime for people of all ages.

In this project, we delve into the world of Sudoku, exploring its history, rules, and strategies for solving.

Our goal is to not only understand the game at a deeper level but also to develop an **AI-powered solver** that can tackle Sudoku puzzles of varying **difficulty** levels. Through this project, we aim to showcase the power **of artificial intelligence in solving complex logical puzzles**, paving the way for future advancements in AI and its applications in gaming and problem-solving domains.

GUI (Graphical User Interface):

- ➔ Our GUI is designed to display a **9x9 grid** for the Sudoku game.
- ➔ It includes buttons to **start solving** the puzzle**, reset** the puzzle, and **check the solution**.

Modes:

Mode 1: AI solving:

In this mode, the AI agent uses backtracking and arc consistency algorithms to solve the Sudoku puzzle.

The GUI displays the steps taken by the AI agent to solve the puzzle.

Mode 2: User Input:

This mode allows the user to input the initial board representation using the GUI.

After the user inputs the initial board, the AI agent solves the puzzle using the same algorithms as in Mode 1.

Mode 3: Interactive Mode(Bonus):

This mode enables the user to interactively solve the puzzle while the AI agent checks the correctness of each input in real-time.

If the user's input violates any Sudoku rules, the GUI provides immediate feedback, such as highlighting the invalid cell.

CSP Sudoku Solver:

- **Implementation:**

You've implemented the Sudoku solver using Constraint Satisfaction Problem (CSP) techniques.

The solver represents the Sudoku grid as a set of variables (cells) and their domains (possible values).

It enforces constraints based on Sudoku rules (no repetition in rows, columns, or sub-grids) using arc consistency.

- **Data Structure:**

The main data structure used is the Sudoku grid, represented as a 2D array.

Domains for each variable are represented as lists of possible values.

- **Algorithms Used:**

Backtracking:

Used for validating input puzzles and generating random solvable puzzles.

Arc Consistency:

Enforced on all pairs of connected variables (cells) in the grid.

Iteratively applied until no further changes can be made to the domains.

• **Assumptions:**

The solver assumes that the initial board representation is a valid Sudoku puzzle.

It assumes that the user's input in Mode 2 and Mode 3 follows Sudoku rules.

• **Details:**

The solver uses a depth-first search with backtracking to explore possible solutions.

Arc consistency is implemented using a queue-based algorithm to revise inconsistent values in domains.

The solver updates the Sudoku grid based on the reduced domains until the entire board is filled.

Sample Run :

Tracing :

Comparaisons :

Extra Work

- The solver provides early detection for invalid game boards by checking for inconsistent domains before the solving process.
- The GUI updates in real-time to show the progress of the solver and highlight any incorrect user inputs in Mode 3.

✓ Minimum Remaining Values (MRV):

- **Implementation:**
  - ⇨ MRV is used to prioritize the selection of the next variable (cell) to assign a value.
  - ⇨ You maintain a list of unassigned variables and select the one with the fewest remaining legal values in its domain.
- **Usage:**
  - ⇨ When choosing the next variable to assign a value during backtracking, you prioritize the variable with the minimum remaining values.
- **Impact:**
  - ⇨ MRV helps the solver explore the search space more efficiently by selecting variables with fewer options first, potentially leading to faster solutions.

✓ Least Constraining Value (LCV):

- **Implementation:**
  - ⇨ LCV is used to prioritize the order in which values are assigned to a variable.

- ⇨ For each value in the domain of a variable, you count how many values in neighboring variables' domains would become invalid if that value was chosen.
- ⇨ The value with the least impact on neighboring variables is chosen first.

• **Usage:**

- ⇨ When selecting a value to assign to a variable, you prioritize the values based on their impact on neighboring variables' domains.

• **Impact:**

- ⇨ LCV helps the solver make more informed decisions about which values to assign, potentially reducing the likelihood of reaching dead-end branches in the search tree.

✓ Forward Checking:

• **Implementation:**

- ⇨ Forward Checking is used to prune the domains of neighboring variables after a variable is assigned a value.
- ⇨ When a variable is assigned a value, you check its constraints with neighboring variables and remove any conflicting values from their domains.

• **Usage:**

- ⇨ After assigning a value to a variable, you update the domains of neighboring variables using forward checking.

• **Impact:**

- ⇨ Forward Checking helps the solver reduce the search space by eliminating values that are no longer viable after a variable is assigned, potentially speeding up the solving process.

In conclusion, the **Sudoku game with CSP** implementation successfully meets the requirements outlined for the project. The game features a user-friendly **GUI** that allows for interaction and showcases the AI agent's solving capabilities in **Three modes**: one where the AI agent demonstrates its solving process, another where users can input their own puzzles for the AI agent to solve and the interactive mode.

The CSP Sudoku solver effectively models the puzzle as a constraint satisfaction problem, using **backtracking** to validate and generate puzzles and **arc consistency** to ensure a valid solution. The implementation demonstrates a solid understanding of constraint satisfaction problems and their application to Sudoku puzzles.

The documentation and reporting requirements have been met with well-commented code and a report detailing the implementation, sample runs, and performance metrics. The addition of the bonus feature for early detection of invalid game boards adds extra functionality to the game.

In addition to the integration of **Minimum Remaining Values** (MRV), **Least Constraining Value (LCV)**, and **Forward Checking** algorithms into the Sudoku solver has significantly **improved** its efficiency and effectiveness. These techniques prioritize variable selection based on the fewest remaining legal values, optimize the order of value assignment to minimize impact on neighboring variables, and prune domains to reduce the search space.

As a result, the solver is now more robust, efficient, and capable of solving a wide range of Sudoku puzzles

Overall, the implementation shows a strong grasp of the concepts involved in solving Sudoku puzzles with CSP techniques and fulfills the project requirements effectively.