

Sudoku

Project *PROP MAS Group 2*

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Project definition

Informal description

Sudoku is a combinatorial placement puzzle. The objective is to fill a 9×9 grid so that each column, each row, and each of the nine 3×3 boxes (that in the context of this project will be called Regions) contains the digits from 1 to 9 only one time each. The puzzle setter provides a partially completed grid, containing from 20 to 32 filled cells, which are called “givens”. Completed puzzles are usually a type of Latin square with an additional constraint on the contents of individual regions.

It is worth pointing out that, even if the grid is filled with numbers, Sudoku is not a mathematical game; number properties are never used to solve the game, which is logic based only.

Terminology definition

Some specific concepts are defined in order to avoid any possible ambiguity in terminology.

- Cell: it is the atomic element of Sudoku and it can contain a value belonging to the set of allowed values $V = \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$ or the value \emptyset , in this case the cell is considered “empty”.
- Sudoku matrix: it is a 9×9 grid where each cell contains a value of V or is empty.
If the matrix contains empty cells it is called “incomplete matrix”, while if all the cells are filled and the constraints of the game are fulfilled then we have a complete Sudoku matrix, or a solution.
An incomplete matrix is a valid “Sudoku instance” if and only if there is only one way to fill its cells in order to make it a Solution.
- Column: taking into account a Sudoku matrix $M_{x,y}$ with $x, y = \{0, 1, \dots, 8\}$ where a cell can be described as cartesian point (x, y) , a Column is the set of cells that have the x-coordinate in common.
E.g.: $\{(0, 0), (0, 1), (0, 2), \dots, (0, 8)\}$ is a Column.
A column is complete when each one of its cells is not empty and when it contains every element of V (with no duplicate).
- Row: taking into account a Sudoku matrix $M_{x,y}$ with $x, y = \{0, 1, \dots, 8\}$ where a cell can be described as cartesian point (x, y) , a Row is the set of cells that have the y-coordinate in common.
E.g.: $\{(0, 0), (1, 0), (2, 0), \dots, (8, 0)\}$ is a Row.
A row is complete when each one of its cells is not empty and when it contains every element of V (with no duplicate).
- Region: taking into account a Sudoku matrix $M_{x,y}$ with $x, y = \{0, 1, \dots, 8\}$ where a cell can be described as cartesian point (x, y) , a Region is a 3×3 block $R_{h,k}$ with $h, k = \{0, 1, 2\}$ that contains all the cells (x, y) so that $3h < x < 3h + 3$ and $3k < y < 3k + 3$.
E.g.: $\{(0, 0), (0, 1), (0, 2), (1, 0), (1, 1), (1, 2), (2, 0), (2, 1), (2, 2)\}$ is $R_{0,0}$ of M .
A region is complete when each one of its cells is not empty and when it contains every element of V (with no duplicate).

- Given: a filled cell which is provided as part of the Sudoku instance. Usually there are between 20 and 32 given in every instance, but they can be less.

Formal problem definition

A player is given an incomplete Sudoku matrix, containing from 20 to 32 filled cells.

The incomplete matrix is a Sudoku instance, that is it was previously checked for accepting only one solution.

The goal of the player is to transform the given instance to a complete matrix; that is a matrix with no empty cells and in which every column, row and region is complete.

Variants

There are many variants of the original Sudoku as it is proposed here, such as Kakuro, Killer Sudoku, Jigsaw and Hypersudoku.

Optionally, the application will offer the user the possibility to play one or more of the following variants of Sudoku:

- Sudoku X:**
It is similar to a standard Sudoku, but both diagonals must also contain digits 1 through 9. Because the diagonals significantly reduce the number of “Unavoidable Sets”, the puzzle can contain less givens than a standard Sudoku.

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

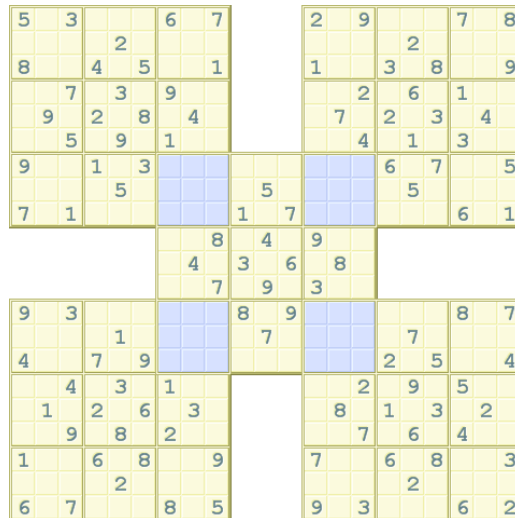
- Hyper Sudoku:**
informally, the rules of the game are very similar to Sudoku.
 - All rows must have all the numbers from 1 - 9 in them (none can be repeated). There are 9 rows in the game.
 - All columns must have all the numbers from 1 - 9 in them (none can be repeated). There are 9 columns in the game.
 - All regions must have all the numbers from 1 - 9 in them (none can be repeated). There are 13 regions in the game.

Moves Left	52	Start	00:00					
	2			3		9	6	
	7	5		9				
6					5		2	
		4		5				
1			3		6		2	9
9			7		4		5	3
			4	6				
2		6	9		8	1		

There are the 9 underlying regions (divided by the dark blue lines) and the 4 overlaying (shown in light blue in the figure).

- Samurai:

Samurai or Gattai-5 is one of the Sudoku Variations with overlapping constituent Sudoku grids. The puzzle has 5 grids, with the center grid overlapping exactly one corner box with each of the remaining grids.

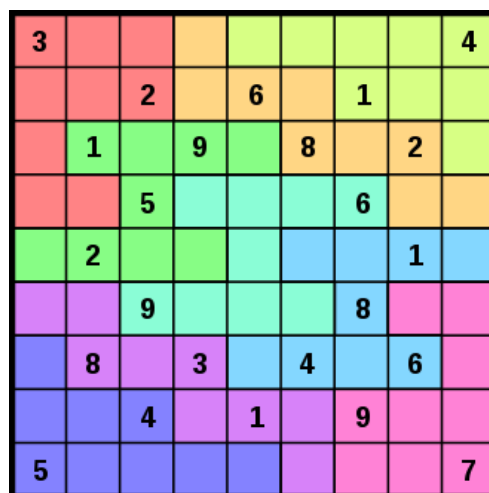


Puzzle designers often leave the overlapping boxes without givens, because these would cause too many eliminations, making the puzzle too easy. In a good Samurai, the constituent puzzles cannot be solved without the information provided by the overlapping regions, but the puzzle as a whole has a single solution.

- Jigsaw Sudoku:

A Jigsaw Sudoku does not have 3x3 boxes, but regions with an irregular shape.

A Jigsaw example:



Application functionalities

- The application proposes a Sudoku instance to the user, who can choose to accept it or change it for another one.
The user can then play following the rules of the game, trying to reach the goal.
- The user will be able to create an incomplete matrix and submit it to the application, which will try to validate it (that is, to check if the matrix is a valid Sudoku instance).
If the input matrix is accepted, the application will solve it and show the solution to the user.
- The user can save the state of the instance at every moment, through a specific procedure.
- The user can load a previously saved state of an instance through a specific procedure.
- The application keeps track of a Ranking of old games, saving together the user name and the time he needed to solve the instance.
- The application interface allows to handle a list of “possible numbers” for every cell.
This function aims to visually help the user to keep track of past thoughts and calculations.
The state of a cell is independent of this list and its content.
- There will be different levels of difficulty for the Sudoku instance proposed to the user who will make the choice before the beginning of every game.
The difficulty level implies:
 - The number of filled cells in the proposed instance.
 - The disposition of those cells.
 - The number of hints available to the user.A hint is an actual help that the application offers to the user.
The system will fill one cell of those that are still empty, randomly.