Sudoku solver using Backtracking

A MINOR PROJECT REPORT

Submitted by

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District June,2022

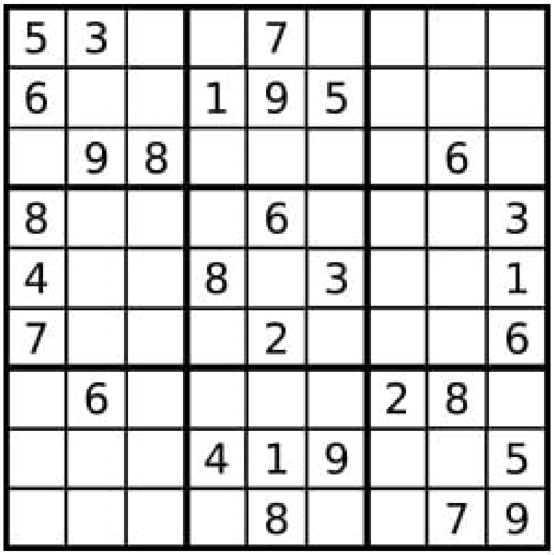
Problem definition:

Write a program to solve a Sudoku puzzle by filling the empty cells.
A sudoku solution must satisfy all of the following rules:

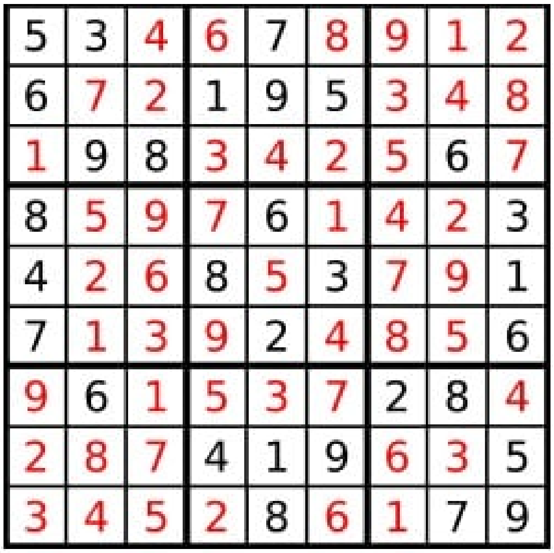
1. **Each of the digits 1-9 must occur exactly once in each row.**
2. **Each of the digits 1-9 must occur exactly once in each column.**
3. **Each of the digits 1-9 must occur exactly once in each of the 9 3x3 sub-boxes of the grid.**

The problem statement can simply be reinterpreted as:-

Given a partially filled 9×9 2D array ‘grid[9][9]’, the goal is to assign digits (from 1 to 9) to the empty cells so that every row, column, and subgrid of size 3×3 contains exactly one instance of the digits from 1 to 9.



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



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

Design Techniques used:

- Backtracking is an algorithmic technique for solving problems recursively by trying to build a solution incrementally, one piece at a time, removing those solutions that fail to satisfy the constraints of the problem at any point in time (by time, here, is referred to the time elapsed till reaching any level of the search tree). Backtracking can also be said as an improvement to the brute force approach. So basically, the idea behind the backtracking technique is that it searches for a solution to a problem among all the available options.

- **In simple words-:*Backtracking can be defined as a general algorithmic technique that considers searching every possible combination in order to solve a computational problem.***

ALGORITHM USED:

Backtracking is simply reverting back to the previous step or solution as soon as we determine that our current solution cannot be continued into a complete one. We will use this principle of backtracking to implement the following algorithm.

Starting with an incomplete board:

1. **Find some empty space**
2. **Attempt to place the digits 1-9 in that space**
3. **Check if that digit is valid in the current spot based on the current board**
4. **a. If the digit is valid, recursively attempt to fill the board using steps 1-3.**
   b. If it is not valid, reset the square you just filled and go back to the previous step.
5. **Once the board is full by the definition of this algorithm we have found a solution.**

CODE :

```
board = [
    [7,8,0,4,0,0,1,2,0],
    [6,0,0,0,7,5,0,0,9],
    [0,0,0,6,0,1,0,7,8],
    [0,0,7,0,4,0,2,6,0],
    [0,0,1,0,5,0,9,3,0],
    [9,0,4,0,6,0,0,0,5],
    [0,7,0,3,0,0,0,1,2],
    [1,2,0,0,0,7,4,0,0],
    [0,4,9,2,0,6,0,0,7]
]

def print_board(bo):
    for i in range(len(bo)):
        if i % 3 == 0 and i != 0:
            print("- - - - - - - - - - - - - ")

        for j in range(len(bo[0])):
            if j % 3 == 0 and j != 0:
                print(" | ", end="")

            if j == 8:
                print(bo[i][j])
            else:
                print(str(bo[i][j]) + " ", end="")


def find_empty(bo):
    for i in range(len(bo)):
        for j in range(len(bo[0])):
            if bo[i][j] == 0:
                return (i, j)  # row, col

    return None
```

```
board = [
    [7,8,0,4,0,0,1,2,0],
    [6,0,0,0,7,5,0,0,9],
    [0,0,0,6,0,1,0,7,8],
    [0,0,7,0,4,0,2,6,0],
    [0,0,1,0,5,0,9,3,0],
    [9,0,4,0,6,0,0,0,5],
    [0,7,0,3,0,0,0,1,2],
    [1,2,0,0,0,7,4,0,0],
    [0,4,9,2,0,6,0,0,7]
]


def solve(bo):
    find = find_empty(bo)
    if not find:
        return True
    else:
        row, col = find
```

```python
    for i in range(1,10):
        if valid(bo, i, (row, col)):
            bo[row][col] = i

            if solve(bo):
                return True

            bo[row][col] = 0

    return False


def valid(bo, num, pos):
    # Check row
    for i in range(len(bo[0])):
        if bo[pos[0]][i] == num and pos[1] != i:
            return False

    # Check column
    for i in range(len(bo)):
        if bo[i][pos[1]] == num and pos[0] != i:
            return False

    # Check box
    box_x = pos[1] // 3
    box_y = pos[0] // 3

    for i in range(box_y*3, box_y*3 + 3):
        for j in range(box_x * 3, box_x*3 + 3):
            if bo[i][j] == num and (i,j) != pos:
                return False

    return True


def print_board(bo):
    for i in range(len(bo)):
        if i % 3 == 0 and i != 0:
            print("- - - - - - - - - - - - - ")

        for j in range(len(bo[0])):
            if j % 3 == 0 and j != 0:
                print(" | ", end="")

            if j == 8:
                print(bo[i][j])
            else:
                print(str(bo[i][j]) + " ", end="")


def find_empty(bo):
    for i in range(len(bo)):
        for j in range(len(bo[0])):
            if bo[i][j] == 0:
                return (i, j)  # row, col
        return None

print_board(board)
solve(board)
print("__________________")
print_board(board)
```

Complexity Analysis:

Time complexity: O(9^(n*n)).
For every unassigned index, there are 9 possible options so the time complexity is O(9^(n*n)). The time complexity remains the same but there will be some early pruning so the time taken will be much less than the naive algorithm but the upper bound time complexity remains the same.

Space Complexity: O(n*n).
To store the output array a matrix is needed.

CONCLUSION:

We have created a solution for a real-life scenario completely from scratch. It helps us to write logic and maintain clean structure in code. This helps in creating solutions for real time problems in our day-to-day life.