SUDOKU SOLUTION VALIDATOR

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***Abstract*— In this report, Sudoku Puzzle is an exceptionally famous puzzle that shows up in the everyday paper that draws in the consideration of many individuals. There are a lot of difficult, unsolved problems about sudoku puzzles and their speculations which makes this puzzle interesting, specifically to a lot of mathematics lovers. There are four levels of difficulty for Sudoku puzzles: Easy, Mild, Hard, Very hard. Every level will have points, with the number of points decided by algorithms of varying degrees of difficulty. It is discussed how to generate a complete puzzle, remove some of the cells, solve the riddle, and use SingleSolution. In our paper, we check if the given Sudoku solution is valid or not.**

Keywords—Sudoku puzzles, single-solution, valid, not valid, difficulty level.

INTRODUCTION

- Sudoku is an enthralling (and addicting) solo game that can keep you engrossed for hours. Solving Sudoku puzzles is both entertaining and challenging. The game is well-known because a Sudoku daily component, similar to crossword puzzles, appears in every major news outlet on every key day. That was more common in more experienced situations. Today's Android and other mobile app shops boast of fantastic free Sudoku games. Simply type in "sudoku games" on Google to find a plethora of Sudoku-related websites.
- Sudoku is a terrific way to actively engage your intellect if you have idle time.
- Sudoku games come in a variety of difficulty levels. Start at the beginning and work your way up the difficulty levels at your own leisure. The best part is that you don't need any prior knowledge of arithmetic or any other topic to play Sudoku.
- Sudoku is a classic puzzle game that has been around for a long time. Sudoku is a logic puzzle in which the objective is to complete a 9x9 grid with numbers in such a way that each row, column, and 3*3 segments contain all digits from 1 to 9.
- Sudoku is a great mental game as well. If you play Sudoku on a regular basis, you will notice an increase in your focus and total brain function.
- Sudoku, a popular Japanese puzzle game, is centered on the placing of numbers in a logical order. Sudoku is a logic game that can be played online or offline. It does not involve any calculations or advanced math skills; your wits and concentration are all that is necessary.
- Sudoku is a game that can be solved. There is only one solution to a properly planned puzzle. There's no need to make educated guesses (although you will be tempted at times). In every scenario, applying simple logic and removing candidates will get the desired result.
- Sudoku does not necessitate the use of mathematics. Sudoku can be played with any nine symbols or colors. Numbers are simply more straightforward.

Why is Playing Sudoku so Popular?

1. Sudoku is a game that may be played anywhere.

Sudoku is a basic and portable puzzle game that can be downloaded to almost any smartphone. Sudoku can be played whenever you have a spare minute during the day, such as at your lunch break or first thing in the morning while drinking your coffee. If you take the train or bus to work, you can play Sudoku on the way. (One of the reasons Sudoku puzzles became so famous in Japan is that millions of people take long train rides to work every morning and enjoy spending the time with puzzles.) People take long

train rides to work every morning and enjoy passing the time with puzzles.

2. Sudoku is a logical game.

Sudoku is a logic puzzle in which players must use deductive reasoning and pattern identification to figure out where the missing numbers should go on the grid. Due to its logical structure, Sudoku is a relatively simple and uncomplicated game to learn how to play.

3. Sudoku is a global game

Sudoku is a universally appealing game that may be enjoyed by people of different cultures and countries since it is a "numbers game" that focuses on numbers rather than letters. Unlike other popular games like Scrabble or crossword puzzles, you don't need to know English or be able to read the English alphabet to play Sudoku.

Unlike games like Trivial Pursuit, you don't need any cultural knowledge to play (for example, you don't need to know anything about a country's movies, music, sports, or politics). Sudoku is a game that can be played by everyone, anywhere on the planet, regardless of language or culture.

4. Sudoku could be beneficial to your health.

Many individuals are becoming more interested in the concept of "brain games," which may help us retain our mental acuity, learning, and mental health throughout our lives. Sudoku is known to improve brain function, and new research suggests that playing Sudoku may reduce the incidence of dementia as people age.

5. Sudoku is fun!

Perhaps self-evident, but Sudoku is just an enjoyable and peaceful method to pass the time. Solving Sudoku problems and gradually working your way to the conclusion is a really rewarding and fulfilling experience. Sudoku puzzles provide a strong sense of success and completion, despite this, they take only a few minutes each day to complete.

Sudoku puzzles are expected to gain in popularity as more people find the joy and mental stimulation that solving these number problems provides.

How to play Sudoku

- Sudoku Rule № 1: Use Numbers 1-9

Sudoku is a puzzle form of competition on a nine-by-nine grid. There are nine "squares" in each row and column (made up of 3 x 3 spaces). Fill in values 1-9 for every row, column, and square (9 slots total), avoiding duplicating any values. Is this a difficult task? Each Puzzle grid begins with some places previously covered in, as you can see in the figure below of an exact Sudoku grid; the more places filled in, the more efficient it is to complete the puzzle.

- Sudoku Rule № 2: Don’t Repeat Any Numbers

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

As we can see, 7 of the 9 slots in the top left square (marked in blue) have already been filled in. Only the numbers 5 and 6 are missing from the square. We may use the process of elimination and deductive reasoning to figure out which numbers need to go in each vacant area by looking at which numbers are missing from each square, row, or column.

For example, in the upper left square, we know we need to add a 5 and a 6 to complete the square, but we can't tell which number to place in which space based on the nearby rows and squares. This indicates we should disregard the upper left square for the time being and focus on filling in gaps in other sections of the grid.

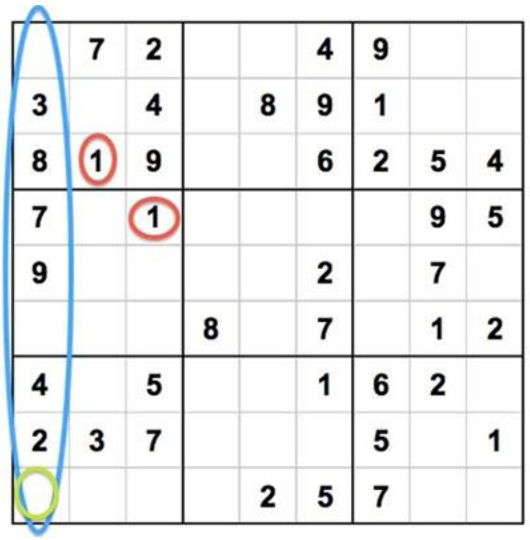
- Sudoku Rule № 3: Don’t Guess

You shouldn't have to guess because Sudoku is a game of logic and reasoning. If you're stumped for a number to put in a given spot, keep scanning the rest of the grid until you find one. But don't try to "force" anything; Sudoku rewards patience, understanding, and pattern detection, not luck or guesswork.

- Sudoku Rule № 4: Use the Elimination Process

What does it mean to use the "process of elimination" when playing Sudoku? Here's an example of what I'm talking about. In this Sudoku grid, only a few digits (1, 5, and 6) are missing from the vertical column on the far left (circled in blue) (seen below).

Because there can't be any duplication of numbers 1-9 within each square, one technique to figure out which numbers can fit in each area is to utilize the "process of elimination" by checking to see which other numbers are already included within each square (or row or column).



The top left and center left squares of the grid already have number 1s, as shown in this example (with number 1s circled in red). This signifies that there is just one spot available in the far left column, circled in green, where a 1 may conceivably go. In Sudoku, you use the process of elimination to determine which spaces are available and which numbers are missing. Then, based on the position of those numbers within the grid, deduce which numbers fit into each space.

Sudoku rules are simple, but the game is endlessly variable, with millions of different number combinations and a wide range of difficulty levels. However, it's all built on the simple concepts of using numbers 1 through 9, deductive reasoning to fill in the blank spaces, inside each square, row, or column, and never repeating any numbers.

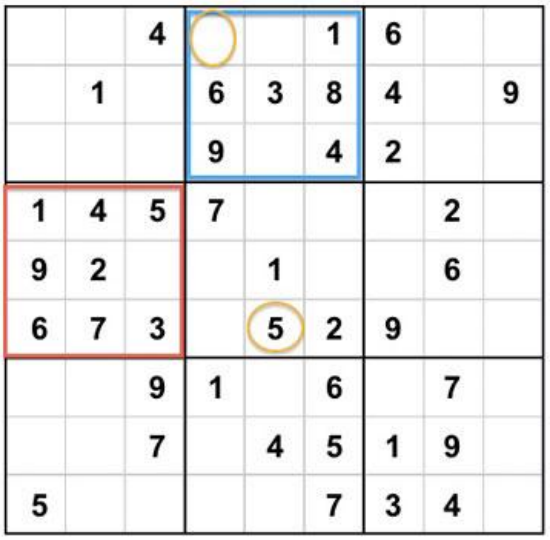
Sudoku Strategy for Beginners

SUDOKU, FORTUNATELY, IS NOT AS DIFFICULT AS IT APPEARS AT FIRST. YOU'LL START TO DETECT PATTERNS IN THE GAME AND FIGURE OUT HOW TO SPOT POSSIBILITIES TO EFFECTIVELY INSERT NUMBERS IF YOU KNOW HOW TO APPROACH THE SUDOKU GRID AND FIND A FEW SHORTCUTS..

Here are some Sudoku strategy recommendations for beginners:

Simple possibilities should be sought for first

You'll find that certain numbers are already in the correct locations when you first start playing Sudoku. When it comes to finishing the rest of the puzzle, this can offer you a tremendous advantage over the competitors. Look for areas where there are already a lot of numbers — within a row, column, or square — when you first start playing Sudoku. The grid will sometimes do part of the work for you!



The red-outlined square, for example, already has 8 of the 9 digits in place in this scenario. The placement of the 9th remaining number is made easier as a result of this (just by checking to see which number is missing). In this situation, the number 8 is absent from the red-outlined area. So, without having to do anything else, we already know that number 8 will fit in that place.

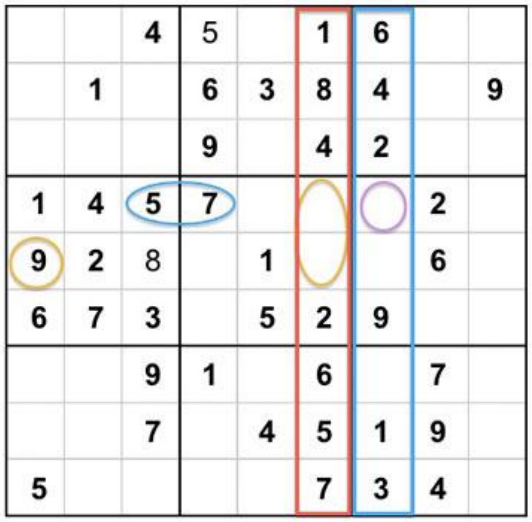
At the same time, there are only three numbers left to be placed in the top center square, which is indicated in blue — numbers 2, 5, and 7.

The number 5 (circled in orange) can be seen in the focus column of the squares below, implying that the two empty spaces in the top (blue) square's top center column CANNOT contain the number 5, implying that the one remaining empty space in the blue square (upper left corner, circled in orange) must contain the number 5. We can easily fill in some gaps in the grid by looking at those squares that already have a lot of numbers in them.

Take a look at the Rows Next to that.

Sudoku is a game of pattern recognition and opportunity detection. You'll improve over time and understand when it's safe to rule out specific numbers, but for Sudoku newbies, scanning nearby rows and columns is the easiest approach to fill an empty area.

In the grid below, the red column, for example, contains two vacant spots (circled in orange). We can see that the only numbers left to insert are 9 and 3 by looking at the other numbers in the red column. We can see a 9 in the middle row of the left centre square if we look to the left to see where other numbers might be (circled in orange).



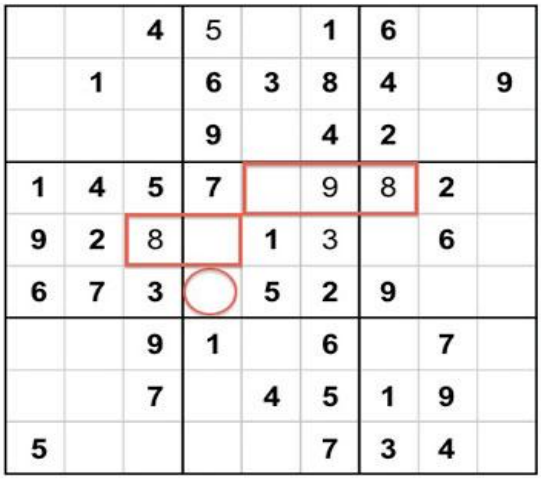
We now know that the number 9 CANNOT be in the red column's bottom empty position; it must be a 3, and the 9 must be in the upper empty slot.

The blue column, on the other hand, has 6 out of 9 places filled. We know the only missing numbers are 5, 7 and 8 only by looking at the numbers that have previously been placed. Looking to the left, In the same row as the purple-circled empty area, you can see the numbers 5 and 7. We know that the numbers 5 and 7 cannot be found in this purple zone, so the number 8 must be present.

Follow Your Momentum

Sudoku is a game of momentum; each time you place a new number, strive to maintain the momentum by seeking for other numbers to place. Every time you enter a number into the grid, it alters, offering new possibilities.

In this grid, for example, the middle square only has three blank slots left, and we can tell by looking at the numbers that 4, 6, and 8 are still missing.



We recently inserted number 8s in the squares next to the upper right corner and left column of the central square, as suggested in the tips above (outlined in red).

As a result, we may delete 8 from those two empty squares, and we know that number 8 belongs in the middle square's lower left corner (circled in red)

We can rule out numbers 4 and 6 once we've put the number 8 – and since we can see number 4 on the top row of the left center square, we know the top vacant spot in the center square CANNOT contain number 4. We'll be able to finish the rest of the central square with a simple process of elimination, and each new number we add to that square will affect the surrounding squares, rows, and columns. Each correctly placed number moves us closer to finishing the puzzle.

Rules of playing a Sudoku puzzle game

- ***First rule:*** Each of the 81 cells on the board can only have the nine digits 1 to 9 and nothing else.

At start, some of the 81 cells will be filled with digits, while the rest will be empty. You must gradually fill in all of the cells while adhering to a few more stringent criteria.

- ***Second rule:*** The numbers 1 through 9 can appear in any row or column without repeating themselves.

When you've filled in all of the game's empty cells, each row and column will have exactly nine digits 1 to 9, with no digits repeating. That will be the correct Sudoku puzzle solution.

This isn't all, though.

- ***Third rule:*** Each of the nine 9-cell primary squares has its own mini world in which you won't be able to insert anything other than the numerals 1 to 9 repeatedly.

Though this rule appears to make the game more difficult, it really aids in answering a Sudoku puzzle to its ultimate correctly filled-in solution.

Note: Now that you know what a Sudoku game is and how to play it, you can start filling in the numbers in the cells and finishing the game. However, after some time has passed (maybe after successfully completing the game), you should return to this spot and continue playing the game. It's

required since you'll be exposed to a systematic strategy that will save you a lot of time and frustration in the future.

II. Literature Survey

Japanese acronym Sudoku is a term that infers the numerals' obligation to stay single, also recognized as Numeral Place, where ‘Su’ stands for number and ‘doku’ for solo. Sudoku is neither a virtuously arithmetic or precise puzzle. It works just as well with letters or other additional symbols in place of the numbers, nevertheless numbers work best. Starting with various digits given in certain cells, the main intention of the riddle is to pass in an arithmetical number from 1 to 9 in an individual cell of a 9*9 grid made up of 3*3 sub squares or sub grids; individually row, column, and sub squares sections must comprise respectively of the numbers 1 to 9 precisely once.

The complete puzzle is mentioned as the game panel, a 3*3 sub grid 3*3 is denoted as a block, and the distinct grid holding the number is stated as a cell in this report.

The sudoku puzzle was originally printed in the city of New York by Dell Magazines, a field puzzle publisher, in their paper ‘Dell Pencil Puzzles and Word Games’. It was initially available under the label "Number game." This primary problem was intended by Howard Garns, a superannuated planner and self-employed puzzle creator. The Latin square, created by Leonhard Euler, is the motivation for this mathematical procedure. Far ahead, in 1984, *Nikoli* became acquainted with the riddle in Japan as "*Suji wa dokushin ni Kagiru*," which means "the number must be solo" or "the numbers must arise only once," and was later shortened to Sudoku. As a replacement of numbers, signs or colours can be utilized in the Sudoku puzzle.

APPROACHES FOR SOLVING:

Technique of Solving through ‘Brute Force’:

Satisfying each empty square by the digits 1 to 9 till an effective result is exposed is a forthright method to answer a Sudoku puzzle. As we can see below, we formulated three dissimilar applications of this function.

APPROACH 1:

The modest problem solver begins at the upper-left square and transfers from left to right, top to bottom, by filling every empty square by a number 1 to 9 till the grid is inacceptable (i.e., a value is repeated in a row, column, or 3x3 area) or till the grid is occupied and valid (i.e., answered). If the grid is inacceptable, the problem solver will move towards the back till it is valid before moving frontward.

APPROACH 2:

The perception of 'domains' is presented in this implementation. Every individual square in a grid takes a domain of up to nine numerical values (1 to 9) in which it is diminished by the numbers in the decussate row, column, and section.

The procedure aids the identical purpose as that of the preceding one, except that it limits the grid's domain before something begins, using only numbers from the initial domains. Whereas the domain limitation requires calculation, this should result in significantly less grid approach retracing.

If a puzzle T with an inventive grid G can be complete with a discrete complete grid E, accordingly a riddle T' with a starting grid G' that is identical to G can be done with a rare whole grid E' that is identical to E. It is claimed that the riddle T' is identical to T. Let iso(E) represent the collection of isomorphic grids derived from E for the sake of clarity. It's worth noting that E is also included in iso (E).

If a riddle T with a starting grid G is fair, then all riddles with starting grids in iso(G) are acceptable as well. In most instances, the amount of invertible grids from E is large. A whole grid, for instance, can even have up to 2*9!*68 = 1,218,998,108,160 invertible entire grids.

In past years, adaptive probing methods like genetic, particle swarm optimization, as well as artificial bee colony algorithms have been used in several Sudoku experiments. Lewis and Mishra et al. provide a full explanation of meta-heuristic techniques. Mishra et al. proposed and examined over ten meta-heuristics based on their effectiveness on Sudoku, although the HS wasn't really mentioned. Coelho and Laporte presented algorithms that are designed primarily for Sudoku challenges and have good solution times. Evaluating the effectiveness of HS to those of other algorithms created expressly to solve Sudoku puzzles will not be a novel addition.

Reduction and what-if interpretation are the two primary techniques to study. The removal of all potential numerals from a cell allows the only option to remain. There are a variety of methods for getting rid of people. Unrivaled prospect elimination is among the most prevalent: it is defined as a cluster of n units with similar possible permutations. If the amount of possible values in each is identical to n, they will be paired. Then if the values that exist as alternatives in other rows, columns, or grids in the same row, column, or grid in the same row, column, or grid in the same row, column units that aren't aligned can be removed.

A unit with only two specified values is chosen and an estimate is generated by using the what-if method. The technique is then repeated with the resultant sudoku; when

no solution can be found, the process is repeated with the alternate digit.

III. Datasets Description

The aim is to determine if the supplied representation of a completed Sudoku problem is legitimate or not, given a 2D array, board[][] of size 9 × 9 that depicts a Sudoku puzzle solution.

EXAMPLES :

1. ***INPUT :***

sudoku = [[7, 9, 2, 1, 5, 4, 3, 8, 6],
[6, 4, 3, 8, 2, 7, 1, 5, 9],
[8, 5, 1, 3, 9, 6, 7, 2, 4],
[2, 6, 5, 9, 7, 3, 8, 4, 1],
[4, 8, 9, 5, 6, 1, 2, 7, 3],
[3, 1, 7, 4, 8, 2, 9, 6, 5],
[1, 3, 6, 7, 4, 8, 5, 9, 2],
[9, 7, 4, 2, 1, 5, 6, 3, 8],
[5, 2, 8, 6, 3, 9, 4, 1, 7]]

EXPECTED OUTPUT :

Sudoku is valid.

2. ***INPUT :***

sudoku = [[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],
[3,4,5,2,8,6,1,7,8]]

EXPECTED OUTPUT :

Sudoku is not valid.

IV. Proposed Methodology

The problem can be solved by checking the following conditions:

1. Determine if each row of the sudoku[][] array has only unique values in the range [1, 9].

2. Determine whether or not each column of the sudoku[][] array has unique values from the range [1, 9].

3. Determine whether or not all of the sudoku[][] array's potential 3 3 submatrices store unique values from the range [1, 9].

Follow the steps below to solve the problem:

1. Traverse the given matrix sudoku[][].
2. Check if the above conditions are satisfied or not.
3. Print "Not valid" if any of the preceding requirements are not met.
4. Otherwise, print “Valid“.

IMPLEMENTATION:

• To determine if all of the entries in the list (sudoku row or sudoku column) are unique, we use the built-in set() function. The set() function, in essence, eliminates any duplicate entries from the list. There are no duplicate elements if the set is 9 elements long.

• To obtain the column elements, we'll use the list comprehension approach.

[item[col num] for sudoku item]

• To retrieve the items for each cell, a slicing process from the Python list is employed.

BELOW IS THE IMPLEMENTATION OF THE ABOVE APPROACH :

```
#validate row

def isRowValid(row_num):

    return len(set(sudoku[row_num])) == 9

#validate column
```

```
def isColValid(col_num):
    col = [item[col_num] for item in sudoku]
    return len(set(col)) == 9
#validate cell
def isCelValid(cel_row, cel_col):
    vals = sudoku[cel_row][cel_col: cel_col+3]
    vals.extend(sudoku[cel_row+1] [cel_col: cel_col+3])
    vals.extend(sudoku[cel_row+2] [cel_col: cel_col+3])
    return len(set(vals)) == 9
#validate sudoku
def validateSudoku():
    for i in range(0,9):
        if not isRowValid(i):
            return False
        if not isColValid(i):
            return False
    for i in range(0, 9, 3):
        for j in range(0, 9, 3):
            print(i, j)
            if not isCelValid(i, j):
                return False
    return True
sudoku = [[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],
          [3,4,5,2,8,6,1,7,8]]
if validateSudoku():
    print("Sudoku is valid.")
else:
    print("Sudoku is not valid.")
```

V. Results and Discussion

For instance, if we have a 9x9 sudoku board. Our job here is to check if it's valid or not. The goal is to fill the vacant cells in a partially filled 9x9 2D array called 'grid [9][9]' with digits (from 1 to 9) so that each row, column, and sub grid of size 3x3 contains exactly one occurrence of the digits from 1 to 9. Validation is required just for the cells that are filled in the table, and it must adhere to a few rules:

1. The numerals 1 through 9 must appear only once in each row.

2. The numerals 1 through 9 must appear only once in each column.

3. The digits 1-9 must appear in each of the grid's 9 (3x3) sub-boxes without duplication.

Ways to solve the problem:

· To determine if all of the elements in the list (sudoku row or sudoku column) are unique, we use the built-in set() method. The set() method, in essence, eliminates all duplicate elements from the list. There are no duplicate elements if the set is 9 elements long.

· To get the column items, we'll use the list comprehension technique.
[item[col_num] for item in sudoku]

· To get the elements for each cell, a slicing process from the Python list is employed.

After understanding exactly how the code works, we come to a conclusion on the basis whether the given sudoku is valid or not. Here are the screenshots stating the results.

```
vyshnavi@vyshnavi-virtual-machine:~$ gedit G12.py
vyshnavi@vyshnavi-virtual-machine:~$ python3 G12.py
Sudoku is valid.
vyshnavi@vyshnavi-virtual-machine:~$ python3 G12.py
Sudoku is not valid.
vyshnavi@vyshnavi-virtual-machine:~$
```

TIME COMPLEXITY :

With two for loops, we're traversing sudoku elements. The temporal complexity of this problem is 2*O(n), which is equivalent to O. (n). This is the most efficient method of resolving the issue.

VI. Conclusion

Solving Sudoku puzzles has become everyone's pastime in the previous decade. People were very interested in accepting challenges to solve the puzzle because of the puzzle's simplicity and the low requirement of mathematical skills. As a result, developers have attempted to design ways for validating puzzles for easier purposes on the determination of whether it's valid or not. It is a popular puzzle game played all over the world. In some cases, candidates are asked questions on Sudoku validation or other Sudoku versions during their interviews. This project is a good technique to determine whether a sudoku puzzle is genuine or not in a faster and more efficient manner. In a short period of time, any level of difficulty can be solved using the given code.

Acknowledgment

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