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01. Problem Statement

Sudoku, originally called **Number Place** is a **9**×**9** grid puzzle based on **logic**, **combinatorial** number placement problem. In the grid, each box contains a number in the range 1-9 satisfying that each column, each row and each **3**×**3** block (i.e. the sub-blocks of the original **9**×**9** grid) contains all the numbers from 1-9 only once.

Solving Sudoku has been a challenging problem in the last decade. The purpose has been to develop more effective algorithm in order to reduce the computing time and utilize lower memory space.

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

Figure 1(a): A Sudoku puzzle

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

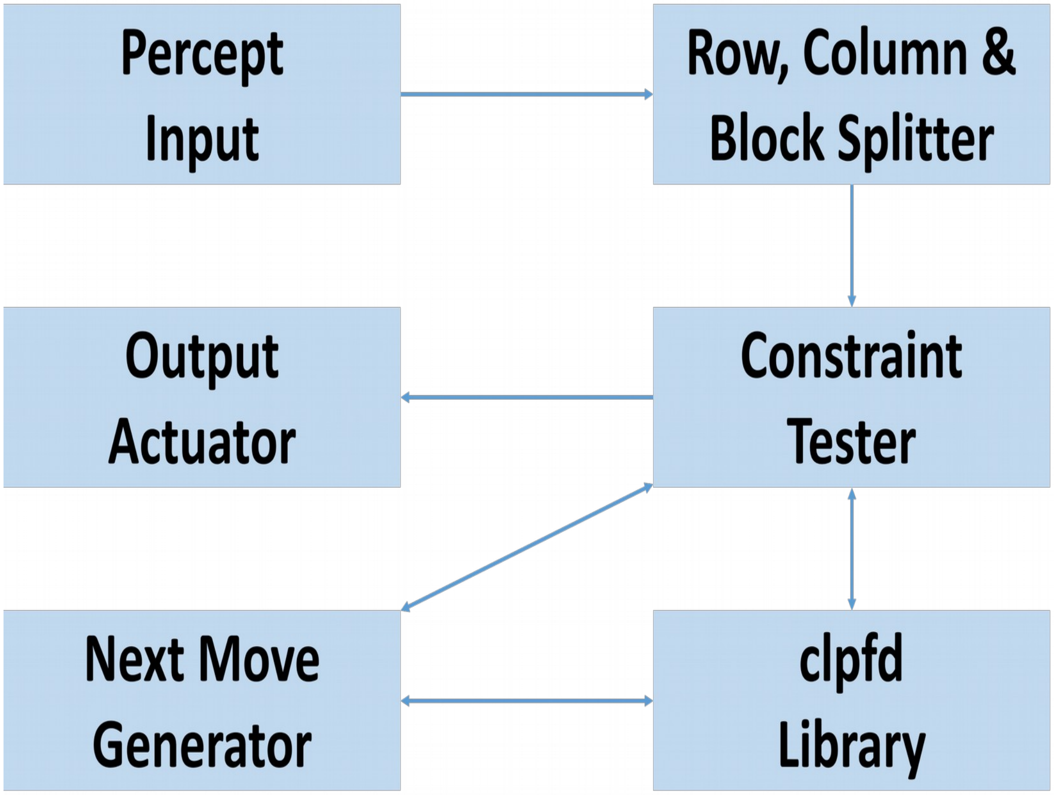
Figure 1(b): Solution of the puzzle

02. Aims and Objectives

The general problem of solving Sudoku puzzles on *n*2×*n*2 grids of *n*×*n* blocks is known to be NP-Complete. Many computer algorithms, such as backtracking and dancing-links can solve most 9×9 puzzles efficiently, but combinatorial explosion occurs as *n* increases, creating limits to the properties of Sudokus that can be constructed, analyzed, and solved as *n* increases. A Sudoku puzzle can be expressed as a graph-coloring problem. The aim is to construct a 9-coloring of a particular graph, given a partial 9-coloring.

The aim of this project is to convert the puzzle to a **Constraints Satisfaction Problem (CSP).** Then implement it in **Prolog** environment to build an expert system which will be able to solve a given sudoku puzzle.

03. Design



04. The Source Code

```
%% sudoku.pl in SWI-Prolog version 8.0.3
:- use_module(library(clpfd)).
sudoku(Puzzle) :-
    flatten(Puzzle, Tmp), Tmp ins 1..9,
    Rows = Puzzle,
    transpose(Rows, Columns),
    blocks(Rows, Blocks),
    maplist(all_distinct, Rows),
    maplist(all_distinct, Columns),
    maplist(all_distinct, Blocks),
    maplist(label, Rows).
blocks([A,B,C,D,E,F,G,H,I], Blocks) :-
    blocks(A,B,C,Block1), blocks(D,E,F,Block2), blocks(G,H,I,Block3),
    append([Block1, Block2, Block3], Blocks).
blocks([], [], [], []).
blocks([A,B,C|Bs1],[D,E,F|Bs2],[G,H,I|Bs3], [Block|Blocks]) :-
    Block = [A,B,C,D,E,F,G,H,I],
    blocks(Bs1, Bs2, Bs3, Blocks).
```

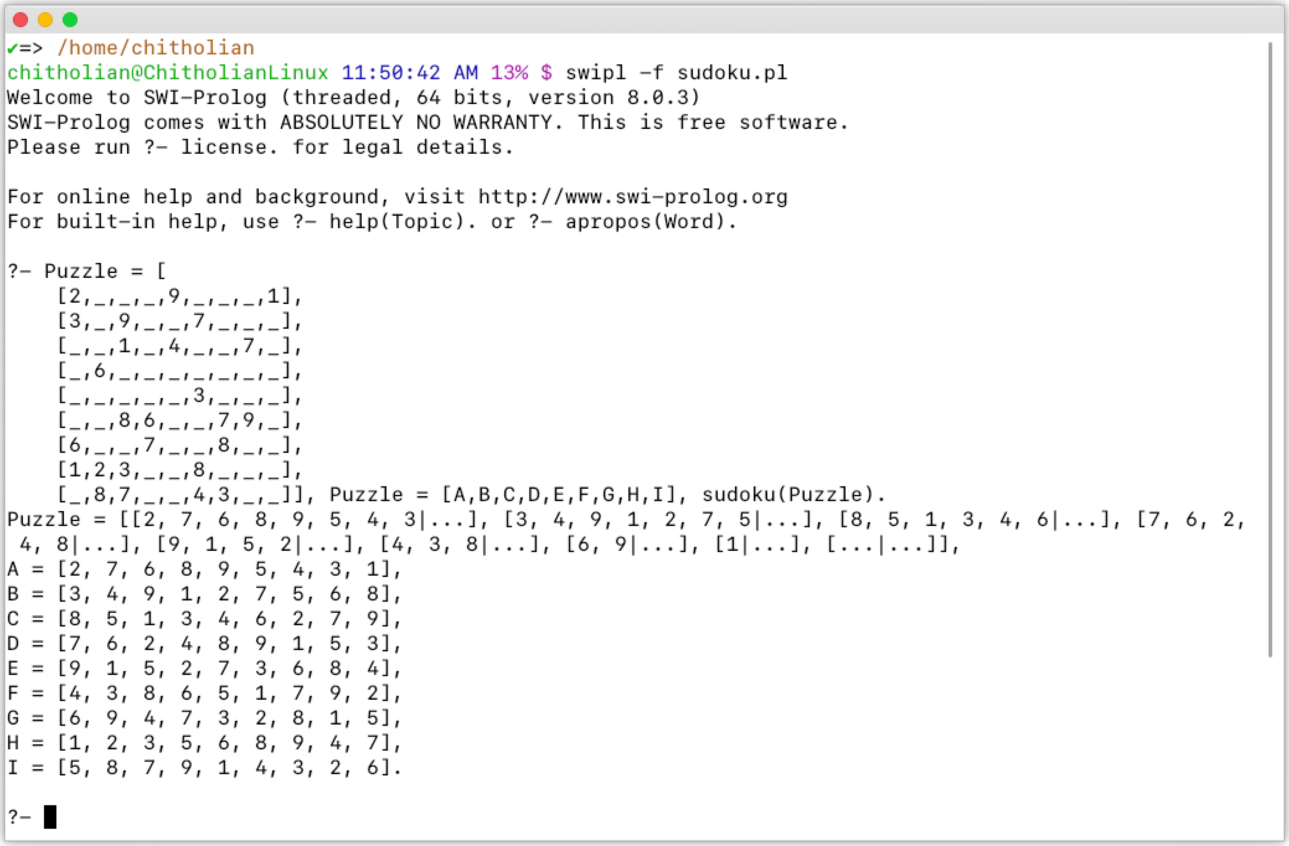
05. Input

```
Puzzle = [
    [2,_,_,_,9,_,_,_,1],
    [3,_,9,_,_,7,_,_,_],
    [_,_,1,_,4,_,_,7,_],
    [_,6,_,_,_,_,_,_,_],
    [_,_,_,_,_,3,_,_,_],
    [_,_,8,6,_,_,7,9,_],
    [6,_,_,7,_,_,8,_,_],
    [1,2,3,_,_,8,_,_,_],
    [_,8,7,_,_,4,3,_,_]], Puzzle = [A,B,C,D,E,F,G,H,I],
sudoku(Puzzle).
```

06. Output

```
A = [2, 7, 6, 8, 9, 5, 4, 3, 1],
B = [3, 4, 9, 1, 2, 7, 5, 6, 8],
C = [8, 5, 1, 3, 4, 6, 2, 7, 9],
D = [7, 6, 2, 4, 8, 9, 1, 5, 3],
E = [9, 1, 5, 2, 7, 3, 6, 8, 4],
F = [4, 3, 8, 6, 5, 1, 7, 9, 2],
G = [6, 9, 4, 7, 3, 2, 8, 1, 5],
H = [1, 2, 3, 5, 6, 8, 9, 4, 7],
I = [5, 8, 7, 9, 1, 4, 3, 2, 6].
```

07. Execution Protocol



```
✔=> /home/chitholian
chitholian@ChitholianLinux 11:50:42 AM 13% $ swipl -f sudoku.pl
Welcome to SWI-Prolog (threaded, 64 bits, version 8.0.3)
SWI-Prolog comes with ABSOLUTELY NO WARRANTY. This is free software.
Please run ?- license. for legal details.

For online help and background, visit http://www.swi-prolog.org
For built-in help, use ?- help(Topic). or ?- apropos(Word).

?- Puzzle = [
    [2,_,_,_,9,_,_,_,1],
    [3,_,9,_,_,7,_,_,_],
    [_,_,1,_,4,_,_,7,_],
    [_,6,_,_,_,_,_,_,_],
    [_,_,_,_,_,3,_,_,_],
    [_,_,8,6,_,_,7,9,_],
    [6,_,_,7,_,_,8,_,_],
    [1,2,3,_,_,8,_,_,_],
    [_,8,7,_,_,4,3,_,_]], Puzzle = [A,B,C,D,E,F,G,H,I], sudoku(Puzzle).
Puzzle = [[2, 7, 6, 8, 9, 5, 4, 3|...], [3, 4, 9, 1, 2, 7, 5|...], [8, 5, 1, 3, 4, 6|...], [7, 6, 2,
 4, 8|...], [9, 1, 5, 2|...], [4, 3, 8|...], [6, 9|...], [1|...], [...|...]],
A = [2, 7, 6, 8, 9, 5, 4, 3, 1],
B = [3, 4, 9, 1, 2, 7, 5, 6, 8],
C = [8, 5, 1, 3, 4, 6, 2, 7, 9],
D = [7, 6, 2, 4, 8, 9, 1, 5, 3],
E = [9, 1, 5, 2, 7, 3, 6, 8, 4],
F = [4, 3, 8, 6, 5, 1, 7, 9, 2],
G = [6, 9, 4, 7, 3, 2, 8, 1, 5],
H = [1, 2, 3, 5, 6, 8, 9, 4, 7],
I = [5, 8, 7, 9, 1, 4, 3, 2, 6].

?- █
```

08. Conclusion

It is seen that the sudoku puzzle problem can be easily solved by making it a constraint satisfaction problem. Moreover, SWI-Prolog's **clpfd** library allows us to set the constraints and get the solution at a very easy and fast way.
Finally, the source code is just around 25 lines, which is also easy to implement as well as easy to understant.