Assignment 4

Introduction to Artificial Intelligence

Pablo Díaz Viñambres : *pablodi@ntnu.no*

October 11, 2022

1 Results

After implementing the backtracking search with AC-3 inference, we were able to solve the Sudoku CSP problem and got the following board results:

Easy board

```
7 8 4 | 9 3 2 | 1 5 6
6 1 9 | 4 8 5 | 3 2 7
2 3 5 | 1 7 6 | 4 8 9
------+-------+------
5 7 8 | 2 6 1 | 9 3 4
3 4 1 | 8 9 7 | 5 6 2
9 2 6 | 5 4 3 | 8 7 1
------+-------+------
4 5 3 | 7 2 9 | 6 1 8
8 6 2 | 3 1 4 | 7 9 5
1 9 7 | 6 5 8 | 2 4 3
```

Medium board

```
8 7 5 | 9 3 6 | 1 4 2
1 6 9 | 7 2 4 | 3 8 5
2 4 3 | 8 5 1 | 6 7 9
------+-------+------
4 5 2 | 6 9 7 | 8 3 1
9 8 6 | 4 1 3 | 2 5 7
7 3 1 | 5 8 2 | 9 6 4
------+-------+------
5 1 7 | 3 6 9 | 4 2 8
6 2 8 | 1 4 5 | 7 9 3
3 9 4 | 2 7 8 | 5 1 6
```

Hard board

```
1 5 2 | 3 4 6 | 8 9 7
4 3 7 | 1 8 9 | 6 5 2
6 8 9 | 5 7 2 | 3 1 4
------+-------+------
8 2 1 | 6 3 7 | 9 4 5
5 4 3 | 8 9 1 | 7 2 6
9 7 6 | 4 2 5 | 1 8 3
------+-------+------
7 9 8 | 2 5 3 | 4 6 1
3 6 5 | 9 1 4 | 2 7 8
2 1 4 | 7 6 8 | 5 3 9
```

Very Hard board

```
4 3 1 | 8 6 7 | 9 2 5
6 5 2 | 4 9 1 | 3 8 7
8 9 7 | 5 3 2 | 1 6 4
------+-------+------
3 8 4 | 9 7 6 | 5 1 2
5 1 9 | 2 8 4 | 7 3 6
2 7 6 | 3 1 5 | 8 4 9
------+-------+------
9 4 3 | 7 2 8 | 6 5 1
7 6 5 | 1 4 3 | 2 9 8
1 2 8 | 6 5 9 | 4 7 3
```

And we also measured the algorithm run time, backtrack function calls and fails:

Board	Time taken	Backtrack calls	Backtrack fails
Easy	54.89 ms	0	0
Medium	57.04 ms	1	0
Hard	79.82 ms	6	2
Very Hard	218.13 ms	55	43

2 Analysis

From this results, we can compare the actions and performance of the algorithm for every board.

On the easy board, the first arc consistency pass is able to solve the entire puzzle. Since we have a very strict assignment from the beginning, we can solve it by only discarding every non arc-consistent value, without having to guess which values are possible or check harder consistency models.

We can't solve the medium board this way, so we enter the backtracking algorithm. Inside the function `select_unassigned_variable` we select one of the variables with the least available values, `0-2`, following the *MRV* heuristic. After testing the value `0-2 = 5` and running the AC-3 inference again, the whole Sudoku gets solved. Because of this, we only get one backtrack function call and we never have to actually *backtrack*, that is, reconsider one of the variable choices we have made.

For the other two boards, multiple backtrack calls are issued, and some of them fail to find a complete solution, making us backtrack and reconsider previous choices. Note that for every value assigned, we are running the AC-3 inference again, keeping the solution consistent and making it easier to find good variable choices, but increasing the run time considerably.