



# Assignment 2

Introduksjon til Kunstig Intelligens

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September 26, 2025

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# 1 Solution

## 1.1 Sudoku solutions

The terminal outputs include: (1) AC-3 time, (2) domain summary after AC-3 (min/max/avg/singles/total), (3) the solved grid, (4) backtracking time, (5) total time, (6) `backtrack()` calls, and (7) `backtrack()` failures.

- **Board (a) Easy:**

```
Solving sudoku_easy.txt:
AC3 time: 0.11596
{'min': 1, 'max': 1, 'avg': 1.0, 'singles': 81, 'total': 81}
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
Backtrack time: 0.00227
total time: 0.11823
Backtrack calls: 82
Backtrack failures: 0
```

Figure 1: Easy sudoku results

*Comment:* AC-3 alone reduces all domains to singletons (81 singles), so backtracking is essentially not needed (0 failures).

- **Board (b) Medium:**

```

Solving sudoku_medium.txt:
AC3 time: 0.1179
{'min': 1, 'max': 4, 'avg': 1.4567901234567902, 'singles': 56, 'total': 118}
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
Backtrack time: 0.00497
total time: 0.12287
Backtrack calls: 273
Backtrack failures: 191

```

Figure 2: Medium sudoku results

- **Board (c) Hard:**

```

Solving sudoku_hard.txt:
AC3 time: 0.11876
{'min': 1, 'max': 6, 'avg': 2.432098765432099, 'singles': 28, 'total': 197}
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
Backtrack time: 0.03452
total time: 0.15328
Backtrack calls: 1288
Backtrack failures: 1206

```

Figure 3: Hard sudoku results

- **Board (d) Very hard:**

```
Solving sudoku_very_hard.txt:
AC3 time: 0.11739
{'min': 1, 'max': 6, 'avg': 2.753086419753086, 'singles': 26, 'total': 223}
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
Backtrack time: 0.36481
total time: 0.48221
Backtrack calls: 14382
Backtrack failures: 14300
```

Figure 4: Very hard sudoku results

## 1.2 Domains after AC-3

- **Easy:** min=1, max=1, avg=1.00, singles=81, total=81
- **Medium:** min=1, max=4, avg=1.4568, singles=56, total=118.
- **Hard:** min=1, max=6, avg=2.4321, singles=28, total=197.
- **Very hard:** min=1, max=6, avg=2.7531, singles=26, total=223.

### 1.3 Timing and search statistics

Board	AC-3 (s)	BT (s)	Total (s)	Calls	Failures
Easy	0.11596	0.00227	0.11823	82	0
Medium	0.11790	0.00497	0.12287	273	191
Hard	0.11876	0.03452	0.15328	1288	1206
Very hard	0.11739	0.36481	0.48221	14382	14300

### 1.4 Discussion

AC-3 enforces arc consistency before the backtracking search by removing values that have no supporting values in neighboring variables. On the easy board, AC-3 collapses all domains to singletons, leaving nothing for backtracking to decide (0 failures). For progressively harder boards, AC-3 still shrinks domains markedly (e.g., Medium from 465 to 118 total candidates), which reduces but does not eliminate the need for search. Consequently, backtracking time and failures increase with difficulty (notably on the very hard board). Maybe choosing an effective strategy to select an unassigned variable, mentioned in [1, p. 177], would have led to better results. I just chose the first variable, which was not in the final solution.

# References

- [1] Stuart Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach*. Pearson, 4 edition, 2020.