A02 - Assignment 2: Constraint Satisfaction Problems

Students:

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Program's solutions

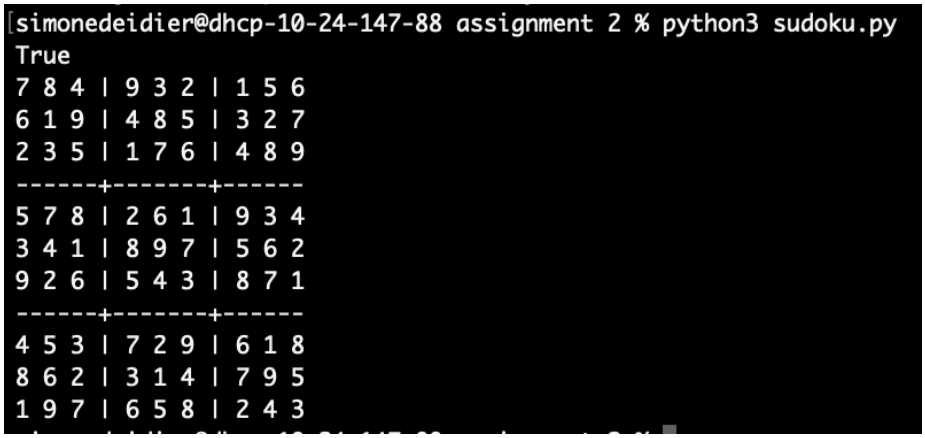

Figure 1: *Solution of our program for the easy Sudoku problem.*

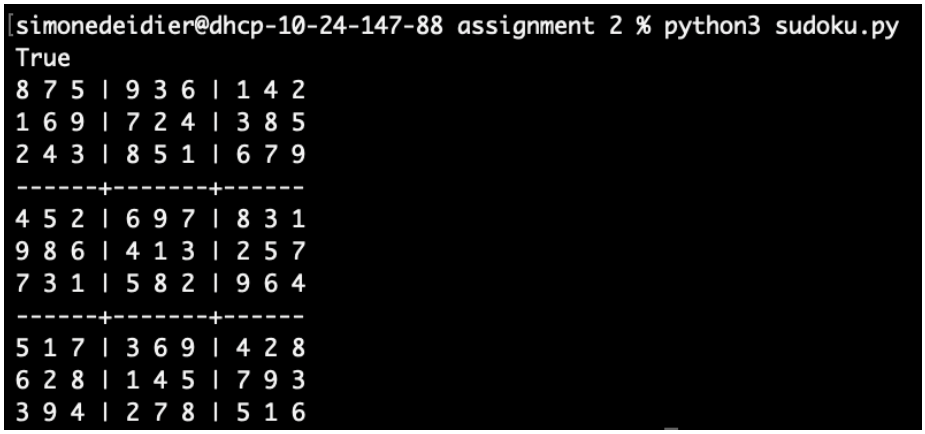

Figure 2: *Solution of our program for the medium Sudoku problem.*

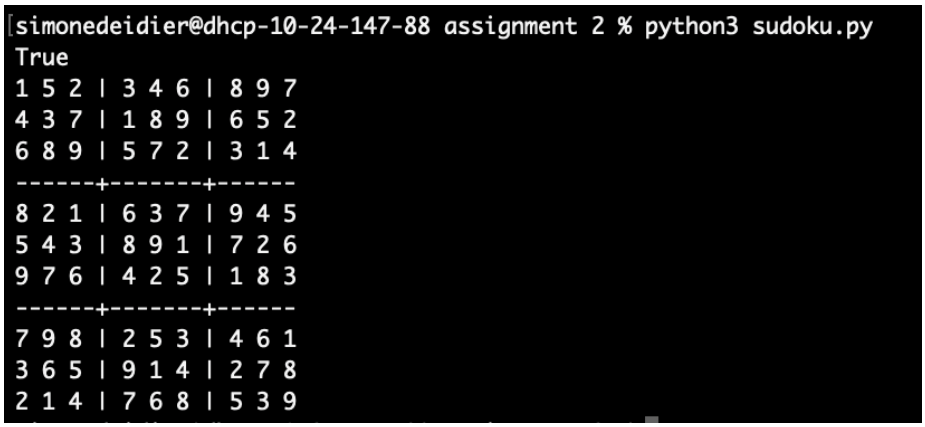

Figure 3: *Solution of our program for the hard Sudoku problem.*

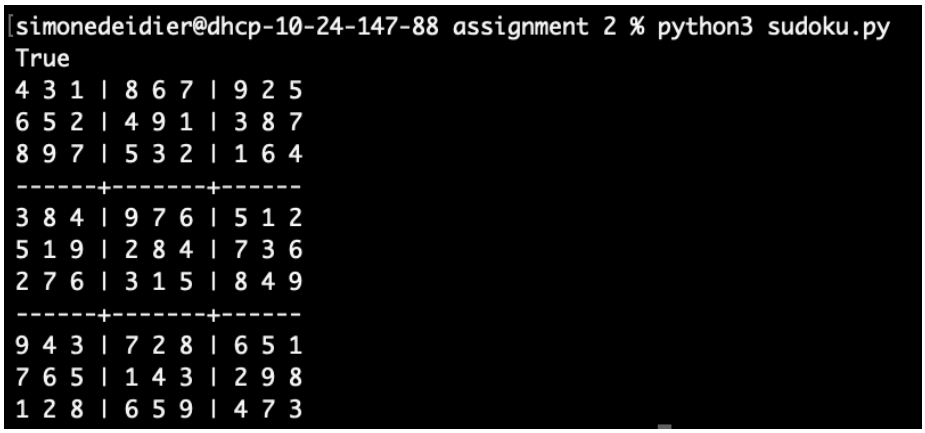

Figure 4: *Solution of our program for the very hard Sudoku problem.*

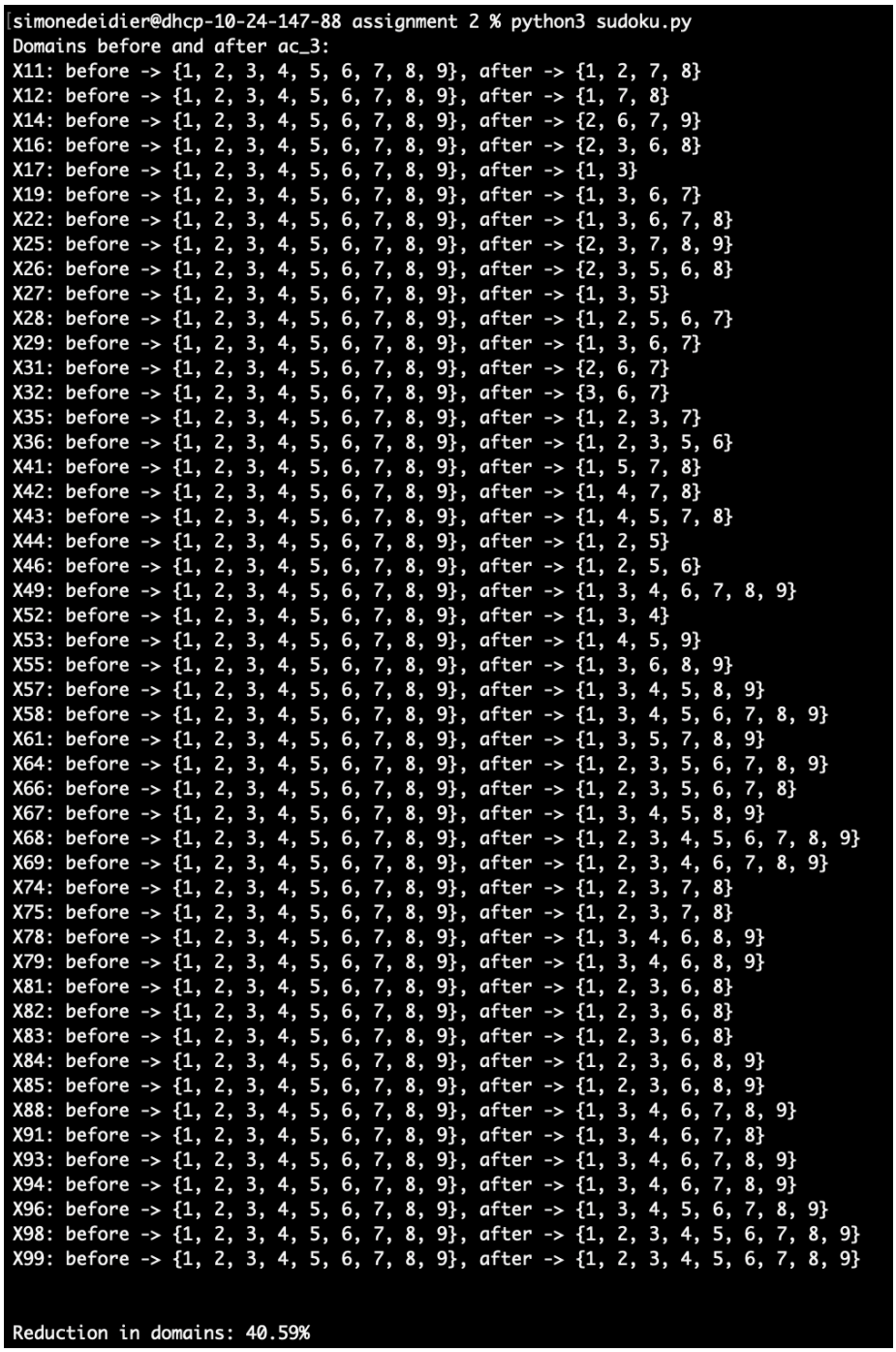

Figure 5: *Domain values for the unknown variabels before and after the* ***AC3*** *algorithm for the easy Sudoku problem.*

```
[simonedeidier@dhcp-10-24-147-88 assignment 2 % python3 sudoku.py
Domains before and after ac_3:
X11: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 6, 7, 8}
X12: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 6, 7, 8}
X13: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {5, 7, 8}
X14: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 9}
X16: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 6}
X17: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 5, 6}
X19: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X22: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 4, 5, 6, 8}
X25: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 9}
X26: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 6}
X27: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 6}
X28: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X29: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X31: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 6}
X32: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 4, 6}
X33: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 9}
X37: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 6}
X39: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X41: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 5}
X42: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 5}
X45: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 9}
X49: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 4, 5, 6, 8}
X52: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 5, 8}
X54: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 6, 8, 9}
X56: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 6, 8}
X58: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 8}
X61: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 6, 7, 8}
X65: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 8}
X68: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X69: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 7, 8, 9}
X71: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 4, 5, 7, 8}
X73: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 7, 8}
X77: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X78: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X79: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 8, 9}
X81: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 8}
X82: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 8}
X83: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 8}
X84: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 8, 9}
X85: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 8, 9}
X88: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 5, 6, 7, 8, 9}
X91: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 8}
X93: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 8, 9}
X94: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 8, 9}
X96: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X97: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X98: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X99: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}


Reduction in domains: 39.12%
```

Figure 6: *Domain values for the unknown variabels before and after the* ***AC3*** *algorithm for the medium Sudoku problem.*

```
simonedeidier@dhcp-10-24-147-88 assignment 2 % python3 sudoku.py
Domains before and after ac_3:
X12: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 5, 6, 8}
X14: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 9}
X16: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 9}
X17: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 6, 8}
X18: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 5, 6, 8, 9}
X21: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 6}
X22: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 5, 6, 7}
X23: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 7}
X24: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 7, 9}
X26: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 6, 8, 9}
X27: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 6, 7, 8}
X28: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 5, 6, 7, 8, 9}
X29: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 5, 7, 8}
X31: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 6, 8}
X32: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 6, 7, 8}
X35: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 7, 8, 9}
X36: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 6, 8, 9}
X38: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 5, 6, 7, 8, 9}
X41: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 8}
X42: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 8}
X43: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3}
X45: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 8}
X48: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 7, 8, 9}
X49: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 7, 8}
X53: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 7, 9}
X54: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 7, 8, 9}
X55: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 7, 8, 9}
X56: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 7, 8, 9}
X57: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 7, 8, 9}
X61: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 8, 9}
X62: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 7, 8, 9}
X65: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 7, 8, 9}
X67: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 6, 7, 8, 9}
X68: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X69: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8}
X72: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 5, 6, 7, 9}
X74: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 7, 8, 9}
X75: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 7, 8, 9}
X78: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8}
X79: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8}
X81: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 5, 6, 7, 8, 9}
X82: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 5, 6, 7, 8, 9}
X83: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 5, 6, 7, 8, 9}
X84: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 5, 7, 8, 9}
X86: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 7, 8, 9}
X87: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8}
X88: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8}
X89: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8}
X92: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 7, 8}
X93: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 7, 8}
X94: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 7, 8}
X96: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8}
X98: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8}


Reduction in domains: 37.11%
```

Figure 7: *Domain values for the unknown variabels before and after the* ***AC3*** *algorithm for the hard Sudoku problem.*[5]

```
simonedeidier@dhcp-10-24-147-88 assignment 2 % python3 sudoku.py
Domains before and after ac_3:
X11: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 5, 8, 9}
X12: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 5, 9}
X14: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 6, 8, 9}
X15: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {5, 6, 8, 9}
X17: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 5, 7, 8, 9}
X18: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 7, 8, 9}
X19: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 7, 8, 9}
X22: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 5, 6, 9}
X23: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 5, 6, 7, 9}
X25: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 5, 6, 8, 9}
X26: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 7, 8}
X28: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 7, 8, 9}
X29: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 5, 7, 8, 9}
X31: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 5, 8, 9}
X32: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 5, 9}
X33: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 5, 7, 9}
X34: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 5, 7, 8, 9}
X36: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 7, 8}
X37: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 5, 7, 8, 9}
X43: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 9}
X44: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 8, 9}
X47: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 4, 5, 7, 8, 9}
X48: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 4, 7, 8, 9}
X49: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 4, 5, 7, 8, 9}
X51: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 4, 5, 8, 9}
X52: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 4, 5, 8, 9}
X53: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 4, 5, 9}
X54: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 4, 7, 8, 9}
X55: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {4, 7, 8, 9}
X56: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 4, 7, 8}
X57: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 4, 5, 7, 8, 9}
X63: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 6, 7, 9}
X64: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 6, 7, 8, 9}
X67: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 6, 7, 8, 9}
X68: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 6, 7, 8, 9}
X69: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 5, 6, 7, 8, 9}
X71: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 6, 9}
X72: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 6, 9}
X73: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 6, 9}
X74: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 6, 7, 8}
X76: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {2, 3, 4, 6, 7, 8}
X77: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 6, 7, 8, 9}
X82: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 5, 6, 7, 9}
X83: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {3, 4, 5, 6, 7, 9}
X85: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 6, 7, 8}
X86: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 3, 4, 5, 6, 7, 8}
X88: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X89: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X91: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7}
X92: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7}
X94: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8}
X95: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8}
X97: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X98: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}
X99: before -> {1, 2, 3, 4, 5, 6, 7, 8, 9}, after -> {1, 2, 3, 4, 5, 6, 7, 8, 9}


Reduction in domains: 34.95%
```

Figure 8: *Domain values for the unknown variabels before and after the* ***AC3*** *algorithm for the very hard Sudoku problem.*

Domains

`backtrack()` calls

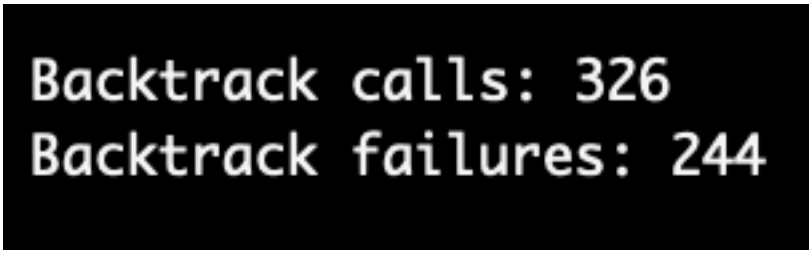

Figure 9: *Count of calls of the* `backtrack()` *function and count of failures for the easy Sudoku.*

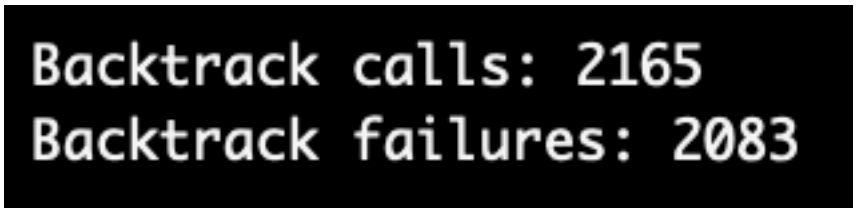

Figure 10: *Count of calls of the* `backtrack()` *function and count of failures for the medium Sudoku.*

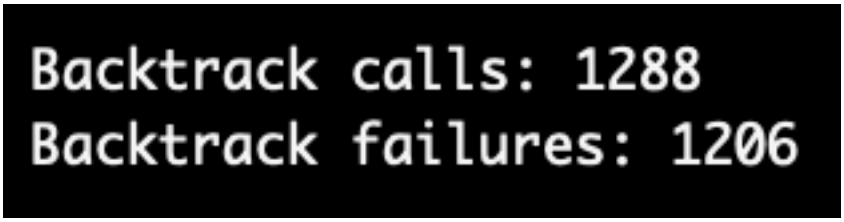

Figure 11: *Count of calls of the* `backtrack()` *function and count of failures for the hard Sudoku.*

Runtime of the backtracking search algorithm, AC-3 and total runtime

Discussion of the results

The **AC-3** algorithm drastically reduces the total runtime when solving some Sudoku problems, especially in more complex configurations, due to its ability to efficiently prune the search space by enforcing arc-consistency early in the process. In simpler terms, **AC-3** eliminates values from variable domains that

Figure 12: *Count of calls of the* `backtrack()` *function and count of failures for the very hard Sudoku.*

```
Runtime of AC-3 algorithm: 0.0180 seconds
Runtime of backtracking search algorithm: 0.0143 seconds
Total runtime of AC-3 and backtracking search algorithms: 0.0324 seconds
```

Figure 13: *Runtime of both the* `backtrack()` * and AC-3 algorithm, with also the total runtime, for the easy Sudoku.*

```
Runtime of AC-3 algorithm: 0.0161 seconds
Runtime of backtracking search algorithm: 0.0713 seconds
Total runtime of AC-3 and backtracking search algorithms: 0.0874 seconds
```

Figure 14: *Runtime of both the* `backtrack()` * and AC-3 algorithm, with also the total runtime, for the medium Sudoku.*

```
Runtime of AC-3 algorithm: 0.0189 seconds
Runtime of backtracking search algorithm: 0.0575 seconds
Total runtime of AC-3 and backtracking search algorithms: 0.0764 seconds
```

Figure 15: *Runtime of both the* `backtrack()` * and AC-3 algorithm, with also the total runtime, for the hard Sudoku.*

```
Runtime of AC-3 algorithm: 0.0177 seconds
Runtime of backtracking search algorithm: 0.6175 seconds
Total runtime of AC-3 and backtracking search algorithms: 0.6351 seconds
```

Figure 16: *Runtime of both the* `backtrack()` * and AC-3 algorithm, with also the total runtime, for the very hard Sudoku.*

are inconsistent with their neighboring constraints, which simplifies the problem before more computationally expensive search algorithms, such as **backtracking**, are applied.

For easier Sudoku puzzles, fewer constraints lead to quicker reductions, as there are more obvious domain eliminations. However, even in more complex configurations, the algorithm still cuts down unnecessary branches of the search tree, speeding up the solving process by reducing the number of possible variable assignments the solver needs to explore. This pre-processing step significantly lowers the runtime in cases where otherwise the problem would involve a larger number of constraint checks or deep recursive searches.

The **backtracking** algorithm, on the other hand, is a depth-first search algorithm that incrementally builds candidates to the solutions and abandons a candidate ("backtracks") as soon as it determines that the candidate cannot possibly be completed to a valid solution. While **backtracking** is powerful and can solve many problems, it can be slow for large and complex problems due to its exhaustive nature. However, when combined with **AC-3**, the search space is significantly reduced, making **backtracking** more efficient and faster in finding solutions. *In summary, the combination of these two algorithms leverages the strengths of both: the pre-processing efficiency of **AC-3** and the exhaustive search capability of **backtracking**.*