# Practice: Solving Sudoku with Evolutionary Computation

The problem consists into solving a sudoku using Evolutionary Computation
What is the size of the search 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 |

**REPRESENTATION**

Phenotype (9x9 matrix)

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

Genotype (missing values permutations)

| |
|---|
| 1, 2, 4, 6, 8, 9 |
| 2, 3, 4, 7, 8 |
| 1, 2, 3, 4, 5, 7 |
| 1, 2, 4, 5, 7, 9 |
| 2, 5, 6, 7, 9 |
| 1, 3, 4, 5, 8, 9 |
| 1, 3, 4, 5, 7, 9 |
| 2, 3, 6, 7, 8 |
| 1, 2, 3, 4, 5, 6 |

**FITNESS**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 | 3 | 1 | 2 | 7 | 3 | 4 | 5 | 6 |
| 6 | 2 | 3 | 1 | 9 | 5 | 4 | 7 | **8** |
| 1 | 9 | 8 | 2 | 3 | **4** | 5 | 6 | 7 |
| 8 | 1 | 2 | 4 | 6 | 5 | 7 | 9 | 3 |
| 4 | 2 | **5** | 8 | 6 | 3 | 7 | 9 | 1 |
| 7 | 1 | 3 | 4 | 2 | 5 | **8** | 9 | 6 |
| 1 | 6 | 3 | 4 | 5 | **7** | 2 | 8 | 9 |
| 2 | 3 | 6 | 4 | 1 | 9 | 7 | 8 | 5 |
| 1 | 2 | 3 | 4 | 8 | 5 | **6** | 7 | 9 |

Fitness = Number of cells

Fitness (example) = 6

**TERMINATION CONDITION:** Until we find an individual with fitness equal to the number of missing values.

**PARENT SELECTION:** Binary tournament, for selecting each parent: randomly choose two individuals from the population and select the one with the best fitness.

**CROSSOVER (OR RECOMBINATION):** One point crossover

| Parent 1 | Parent 2 | Offspring |
|---|---|---|
| 1, 2, 4, 6, 8, 9 | 8, 9, 2, 4, 1, 6 | 1, 2, 4, 6, 8, 9 |
| 2, 3, 4, 7, 8 | 7, 3, 2, 4, 8 | 2, 3, 4, 7, 8 |
| 1, 2, 3, 4, 5, 7 | 5, 4, 3, 7, 1, 2 | 1, 2, 3, 4, 5, 7 |
| 1, 2, 4, 5, 7, 9 | 9, 5, 7, 2, 4, 1 | 1, 2, 4, 5, 7, 9 |
| 2, 5, 6, 7, 9 | 6, 2, 5, 9, 7 | 6, 2, 5, 9, 7 |
| 1, 3, 4, 5, 8, 9 | 1, 8, 9, 4, 3, 5 | 1, 8, 9, 4, 3, 5 |
| 1, 3, 4, 5, 7, 9 | 7, 5, 4, 1, 3, 9 | 7, 5, 4, 1, 3, 9 |
| 2, 3, 6, 7, 8 | 8, 6, 2, 7, 3 | 8, 6, 2, 7, 3 |
| 1, 2, 3, 4, 5, 6 | 5, 4, 1, 6, 2, 3 | 5, 4, 1, 6, 2, 3 |

**MUTATION:** Random Swap

| Original | Mutated |
|---|---|
| 1, 2, 4, 6, 8, 9 | 1, 2, 4, 6, 8, 9 |
| 2, 3, 4, 7, 8 | 2, 8, 4, 7, 3 |
| 1, 2, 3, 4, 5, 7 | 1, 2, 3, 4, 5, 7 |
| 1, 2, 4, 5, 7, 9 | 1, 2, 4, 5, 7, 9 |
| 2, 5, 6, 7, 9 | 2, 5, 6, 7, 9 |
| 1, 3, 4, 5, 8, 9 | 1, 3, 4, 5, 8, 9 |
| 1, 3, 4, 5, 7, 9 | 1, 3, 4, 5, 7, 9 |
| 2, 3, 6, 7, 8 | 2, 3, 6, 7, 8 |
| 1, 2, 3, 4, 5, 6 | 1, 2, 3, 4, 5, 6 |

**SURVIVAL SELECTION:** Save only the best individuals from the parents and children.

**PSEUDOCODE:**

Parameters:
N: population size
$P_{crossover}$: Crossover probability
$P_{mutation}$: Mutation probability

1. Calculate the missing values
2. $P_0$ <- Generate the initial population as random permutation of the missing values
3. $F_0$ <- Fitness of individuals in $P_0$
4. Elite <- The best individual of $P_0$
5. k = 0
6. While termination condition is not met:
7. k = k+1
8. For each new individual in $P_k$:
9. If random() <= $P_{crossover}$:
10. Select two parents with binary tournament
11. Create a new offspring as the parents recombination
12. Else:
13. Select one parent with binary tournament
14. Create a new offspring as the copy of the parent
15. If random() <= $P_{mutation}$:
16. Mutate the offspring with random swap
17. $F_k$ <- Fitness of individuals in Pk
18. Update Elite
19. $P_k$ <- The best individuals from $P_{k-1}$ and $P_k$
20. Return Elite