

---

## Import data

```
In[ ]:= data = Import[FileNameJoin[{
    NotebookDirectory[],
    "data",
    "berlin52.tsp - 52 locations in Berlin (Germany) (Groetschel).txt"
}], "Table"] [[7 ;; -2]] [[All, 2 ;;]];

In[ ]:= optTour = ToExpression /@ (Import[FileNameJoin[{
    NotebookDirectory[],
    "data",
    "berlin52.opt.tour - Optimum tour for berlin52.txt"
}], "Data"] [[5 ;; -3]]);
```

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## Helper functions

```
In[ ]:= distanceMatrix = DistanceMatrix[data];

In[ ]:= Clear[f]
f[x_] :=
    Total[distanceMatrix[[#1]], #2]] & /@ Partition[x, 2, 1]] + distanceMatrix[x[[1]], x[[1]]]

In[ ]:= Clear[inverse]
inverse[permutation_, i1_, j1_] := Module[
    {p = permutation, sortedij = Sort[{i1, j1}], i, j, oldi},
    i = sortedij[[1]];
    j = sortedij[[2]];
    If[
        j - i == Length[p] - 1,
        oldi = p[[i]]; p[[i]] = p[[j]]; p[[j]] = oldi; p,
        Join[p[[1 ;; i - 1]], Reverse[p[[i ;; j]]], p[[j + 1 ;; Length@p]]
    ]
]

In[ ]:= Clear[insert]
insert[permutation_, i_, j_] := Module[
    {p = permutation, element = permutation[[j]]},
    p = Drop[p, {j}]; Insert[p, element, i]
]

In[ ]:= Clear[swap]
swap[permutation_, i_, j_] := Module[
    {p = permutation, element = permutation[[i]]},
    p[[i]] = p[[j]]; p[[j]] = element; p
]
```

```
In[ ]:= Clear[minimalPermut]
minimalPermut[permutation_, i_, j_] := MinimalBy[
  {inverse[permutation, i, j], insert[permutation, i, j], swap[permutation, i, j]}, f][[1]]
```

## Simulated Annealing v

```
In[ ]:= Clear[simulatedAnnealing]
simulatedAnnealing[permutation_, maxIteration_,
  initialTemperature_, endTemperature_, a_] := Module[
  {x = permutation, t = initialTemperature, i, y, randomChoice, p, fx, fy},
  Do[
    x = MinimalBy[Table[
      randomChoice = RandomSample[x, 2];
      y = minimalPermut[x, randomChoice[[1]], randomChoice[[2]]];
      fy = f[y];
      fx = f[x];
      If[
        fy ≤ fx,
        x = y,
        p = Exp[ $\frac{-(fy - fx)}{t}$ ]; If[RandomReal[] ≤ p, x = y]
      ];
      {x, fx},
      {i, Length[permutation]}], Last][[1, 1]];
    t = t * a;
    If[t ≤ endTemperature, Break[]],
    {i, maxIteration}];
  x
]
```

```
In[ ]:= x = RandomSample[Range[52]]
f[x]
```

```
Out[ ]:= {26, 19, 45, 51, 17, 5, 41, 25, 44, 40, 52, 1, 28, 27, 39,
  18, 35, 38, 20, 48, 29, 32, 24, 13, 37, 6, 8, 30, 43, 22, 3, 2, 50, 10,
  4, 36, 9, 15, 7, 46, 31, 14, 33, 49, 12, 11, 21, 16, 47, 23, 34, 42}
```

```
Out[ ]:= 31688.
```

```
In[ ]:= solutionSimulatedAnnealing = simulatedAnnealing[x, 1000, 0.025, 10-10, 0.99]
f[solutionSimulatedAnnealing]
```

General: Exp[-16024.] is too small to represent as a normalized machine number; precision may be lost.

General: Exp[-23641.6] is too small to represent as a normalized machine number; precision may be lost.

General: Exp[-20573.4] is too small to represent as a normalized machine number; precision may be lost.

General: Further output of General::munfl will be suppressed during this calculation.

```
Out[ ]:= {11, 51, 33, 43, 10, 9, 8, 41, 19, 45, 32, 49, 1, 22, 50, 20,
          23, 31, 18, 3, 17, 21, 42, 7, 2, 30, 29, 16, 44, 34, 35, 36, 39, 40,
          37, 38, 15, 4, 6, 5, 24, 48, 46, 25, 12, 28, 27, 26, 47, 13, 14, 52}
```

```
Out[ ]:= 7835.1
```

```
In[ ]:= optTour
f[optTour]
```

```
Out[ ]:= {1, 49, 32, 45, 19, 41, 8, 9, 10, 43, 33, 51, 11, 52, 14, 13,
          47, 26, 27, 28, 12, 25, 4, 6, 15, 5, 24, 48, 38, 37, 40, 39, 36, 35,
          34, 44, 46, 16, 29, 50, 20, 23, 30, 2, 7, 42, 21, 17, 3, 18, 31, 22}
```

```
Out[ ]:= 7544.37
```

```
In[ ]:= Clear[statistic]
statistic[n_] := Quiet@Module[{solutions},
  solutions =
    f /@ Table[simulatedAnnealing[RandomSample[Range[52]], 1000, 0.025, 10-10, 0.99], {n}];
  Grid[Transpose@{Join[StringJoin[ToString[#], " вариант"] & /@ Range[n],
    {"Худший", "Средний", "Лучший", "Оптимум"}], Join[solutions,
    {Max[solutions], Mean[solutions], Min[solutions], f[optTour]}]}, Frame → All]
]
(*statistic[10]*)
```

In[ ]:=

"1 вариант"	8318.34159377993`
"2 вариант"	8188.071370541938`
"3 вариант"	8009.167382852811`
"4 вариант"	7742.646171734603`
"5 вариант"	7710.826460219718`
"6 вариант"	7828.470560216607`
"7 вариант"	7941.317258102208`
"8 вариант"	7544.36590190409`
"9 вариант"	8109.389334715343`
"10 вариант"	7930.795009787471`
"Худший"	8318.34159377993`
"Средний"	7932.339104385472`
"Лучший"	7544.36590190409`
"Оптимум"	7544.365901904091`

Out[ ]:=

1 вариант	8318.34
2 вариант	8188.07
3 вариант	8009.17
4 вариант	7742.65
5 вариант	7710.83
6 вариант	7828.47
7 вариант	7941.32
8 вариант	7544.37
9 вариант	8109.39
10 вариант	7930.8
Худший	8318.34
Средний	7932.34
Лучший	7544.37
Оптимум	7544.37