

# Simulated Annealing Algorithm for the Traveling Salesman Problem



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## Simulated Annealing

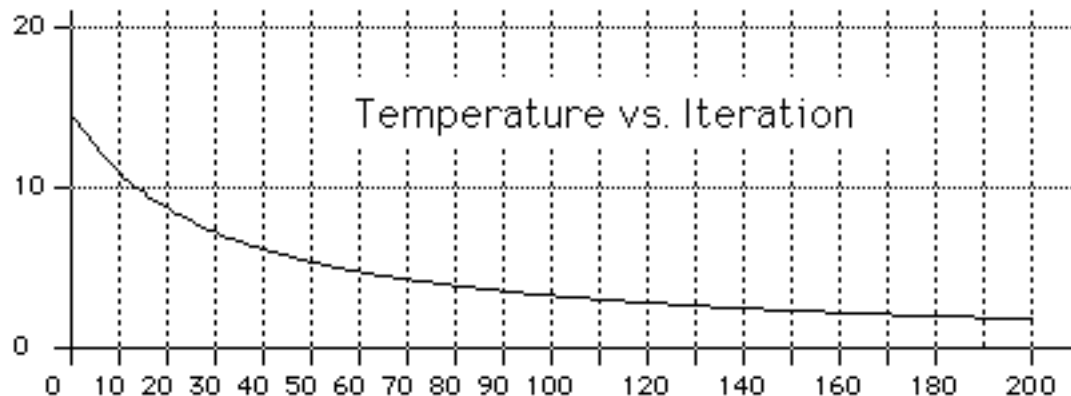
Simulated annealing is similar to Lin's k-exchange algorithm, except that an exchange that results in an increase in the tour length is accepted with a positive probability.

(This probability varies inversely with the magnitude of the increase, and for a given increase, decreases as the algorithm progresses. . .)

## "Simulated Annealing"

- a heuristic search approach
- a move is made to any neighboring solution with equal or lower cost
- if the neighbor increases the cost by  $\Delta > 0$ , then the move is accepted with probability  $P\{\text{accept } \Delta\} = e^{-\Delta/T}$  where T is the current "temperature" of the system
- the system is "cooled" according to some "cooling schedule"

*After each iteration, the temperature is reduced, according to a "cooling schedule"*

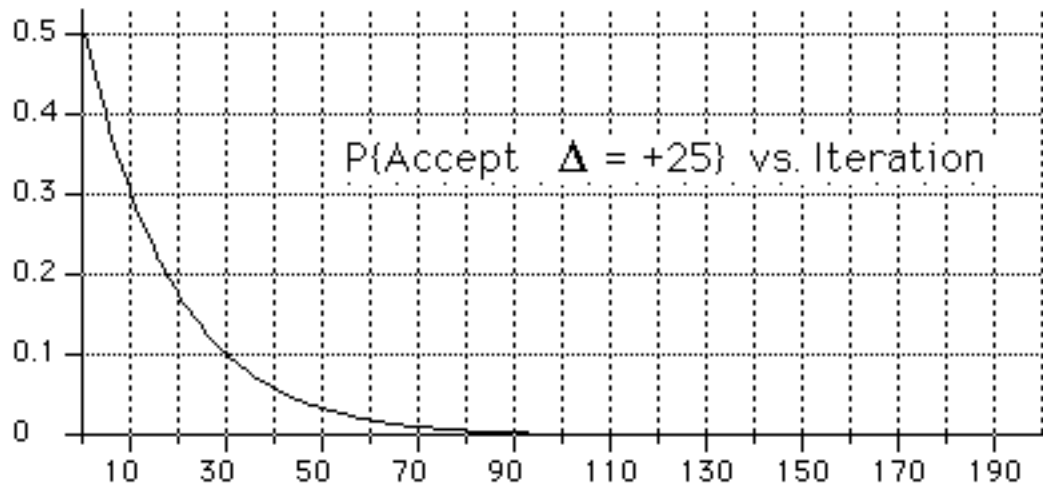


$$T_{i+1} = \frac{T_i}{1 + \beta T_i}$$

where  $\beta = \frac{(T_0 - T_f)}{M T_0 T_f}$

&  $\left\{ \begin{array}{l} T_0 = \text{initial temperature} \\ T_f = \text{final temperature} \\ M = \# \text{ of iterations} \end{array} \right.$

*As the system "cools", the probability of accepting an increase (of 25) decreases:*



$$P\{\text{accept } \Delta\} = e^{-\Delta/T}$$

## Simulated Annealing (starting with random tour)

Temperature will decrease from 36.067 to 2.171

Cooling parameter beta is 0.002163955657

```
Tour # 1 is 1 / 11 7 / 4 2 3 8 10 5 12 9 6 1
Length: 685      Improvement: 44
Tour # 2 is 1 / 4 7 11 / 2 3 8 10 5 12 9 6 1
Length: 693      Improvement: -8
Tour # 3 is 1 / 2 11 7 4 / 3 8 10 5 12 9 6 1
Length: 687      Improvement: 6
Tour # 4 is 1 / 3 4 7 11 2 / 8 10 5 12 9 6 1
Length: 707      Improvement: -20
Tour # 5 is 1 / 12 5 10 8 2 11 7 4 3 / 9 6 1
Length: 698      Improvement: 9
Tour # 6 is 1 / 9 3 4 7 11 2 8 10 5 12 / 6 1
Length: 720      Improvement: -22
Tour # 7 is 1 9 / 7 4 3 / 11 2 8 10 5 12 6 1
Length: 694      Improvement: 26
Tour # 8 is 1 9 / 11 3 4 7 / 2 8 10 5 12 6 1
Length: 677      Improvement: 17
```

Best Tour: 1 2 3 11 9 10 8 7 6 5 4 12 1, with length 321

CPU time for simulated annealing: 123.35 seconds

