Machine Learning (ECE 4850)

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Project 2

Submission Type: Online, Canvas

Reading

- Simulated Annealing on Wikipedia web page.
- Materials we learned in class including the optimization method of simulated annealing.
- Uploaded Files related to Simulated Annealing on Canvas.

Problem: Simulated annealing is a Monte Carlo method that can be used to seek the optimum of a multimodal function. In this assignment, you'll get a chance to try this out on a problem with a discrete domain.
The traveling salesman problem is an optimization problem in which the minimum length path through a circuit is found. Here are N cities with positions (x_i, y_i). The problem is to find a path which visits each city **exactly once** and returns to the original city.

Since there are N cities, there are N! different orders in which they may be visited. A configuration is a permutation of the numbers 1, 2,…, N as the order in which the cities are visited.

Let $\boldsymbol{\sigma}$ =$(\sigma_1, \sigma_2, \ldots, \sigma_N)$ denote a permutation of the numbers 1, 2,…, N. For example, when N = 5, we might have

$$\boldsymbol{\sigma} = (\sigma_1, \sigma_2, \sigma_3, \sigma_4, \sigma_5) = (3,5,2,1,4)$$

denoting that the order of cities is first 3, then 5, etc. The objective function as function of $\boldsymbol{\sigma}$ is defined as

$$E(\boldsymbol{\sigma}) = \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} (\boldsymbol{x}_{\sigma_i} - \boldsymbol{x}_{\sigma_{i+1}})^2 + (\boldsymbol{y}_{\sigma_i} - \boldsymbol{y}_{\sigma_{i+1}})^2$$

with the conventional that point N + 1 is identified with the point 1. In this notation, the problem is to identify the permutation $\boldsymbol{\sigma}$ that minimizes $E(\boldsymbol{\sigma})$.

Rearrangement of the sequence of cities may be done in a variety of ways. One method that has been suggested is to make one of the following moves:

- A randomly selected section of a path is removed, then replaced with the same cities running in the opposite order.
- A randomly selected section of path is removed, then placed between two cities on another randomly selected part of the path.

Another method is to simply transpose two cities in a path. Let ΔE denote the change in energy

$$\Delta E = \mathrm{E(new\ configuration)} - \mathrm{E(old\ configuration)}$$

If $\Delta E < 0$, the new configuration is always accepted. If $\Delta E > 0$, it is accepted with probability $e^{-\Delta E/T}$, where T is a temperature determined by an annealing schedule. The temperature starts at some high value, and is decreased by some schedule to a small value. You may want to run for many iterations at each temperature.

Write a simulated annealing program in MATLAB/Python to find the minimum distance circuit between the cities with positions given by

```
xpos  =  [57  16  14  47  90  55  3  5   80  45  38  78  36  53  71  87  32  65  97  7 ];
ypos  =  [80  42  72  49  80  35  7  59  91  19  43  74  3   94  76  55  18  49  51 99];
```

a) Find the lowest cost path possible. Plot the minimum cost path. Turn in your program code, a description of how you designed the algorithm including your annealing schedule, a plot of temperature as a function of time (iteration) and fitness as a function of time, and indicate what your lowest-cost path is.

b) Submit your codes along with a technical report that contains an introduction about the project, a section on the results (with figures), and a conclusion section.

c) Prepare a set of slides with your teammate (if you have any) and be prepared to present your work in class for **15 minutes**.

Good Luck