ISE 5113 Advanced Analytics and Metaheuristics
Homework #5

Instructor: Charles Nicholson

Due: See course website for due date

Requirement details

1. Homeworks are to be completed in teams of one or two. If team members disagree on an answer, you can record solutions corresponding to each member (please clearly mark which solution belongs to which team member).
2. Your primary submission will be a single Word or PDF document and must be of professional quality: clean, clear, concise, yet thoroughly responsive.
3. Any code (e.g., Python) must also be submitted separately. Your code MUST be well-documented. Failure to submit the files will result in a penalty. For this problem you may submit separate code for each problem or submit a single file with multiple functions associated with each coding problem.
4. You cannot use preexisting Python packages for heuristics or metaheuristics. In fact, other than `numpy, copy, random`, and other basic utilities, you should seek specific permission from the instructor if you have any doubt. That is, *you* are responsible for creating the logic yourself.

In this assignment you will modify some provided Python code to implement a Simulated Annealing algorithm to solve the same instance of the knapsack problem. After implementing the code and solving the problem, please summarize your results in a table similar to Table 1.

Table 1: Example of results summary (numbers are not realistic)

t_0	Cooling, t_k	M_k	# of temps	Iterations	# Items Selected	Weight	Objective
1000	$\frac{t_0}{1+0.9k}$	10	900	2102	87	32	184
800	$0.99t_{k-1}$	50	40	5333	17	230	1284
1200	$0.99t_{k-1}$	50	40	5333	17	230	1284
etc.							

Knapsack Problem Definition Given n different items, where each item i has an assigned value (v_i) and weight (w_i), select a combination of the items to maximize the total value without exceeding the weight limitations, W, of the knapsack.

IMPORTANT!: When generating random problem instance set $n = 150$ and use the provided seed value for the random number generator. The max weight is 1500.

Question 1: Simulated Annealing (70 points)

Using the provided Python code as a base, implement Simulated Annealing in code. Please address the following:

- Explanation of how you determine the initial temperature.
- At least three different temperature cooling schedules (the temperature update procedure) and explore some options for the number of iterations performed at a given temperature (M_k).
- Explanation of the stopping criterion.

Apply the code to the random problem instance and determine the best solution and objective value using the multiple variations of your algorithm.

Question 2: Metaheuristics and Metaphors (30 points)

As you should have read in the article "Metaheuristics – the metaphor exposed", there are variety of so-called "novel" metaheuristic algorithms inspired by natural phenomenon. While some such methods are truly novel and powerful techniques, many others are simply variations or nuances of existing techniques with a colorful story behind it that somehow, to the detriment of the scientific community, get published.

In this problem, I am asking you to create your own, "novel' metaheuristic based on creative combinations/nuances of the existing methods we have discussed. I would like you to use at least 4 elements from the following list, but feel free to go crazy.

- hill-climbing (or stochastic hill climbing)
- random walk, random restarts, stochastic hill climbing
- local beam search (or the stochastic version)
- simulated annealing
- guided local search
- variable neighborhood search
- tabu search
- path relinking
- concepts from genetic algorithms (e.g., crossover, mutation, insertion, etc.)
- concepts from particle swarm optimization (e.g., velocity, inertial weight, information sharing, etc.)

Your deliverable is a well-written piece of pseudocode that combines a subset of these elements *plus* whatever else you would like to throw in.

For an *extra 8 points of credit*, please (i) name your metaheuristic based off of some natural or semi-natural phenomenon and (ii) describe how it relates to your concept. Feel free to wax poetic.

Your metaheuristic name and storyline must be new!

Note: COVID-19 and Sperm Whales ares already taken...

- "Coronavirus Optimization Algorithm: A Bioinspired Metaheuristic Based on the COVID-19 Propagation Model" `https://www.liebertpub.com/doi/full/10.1089/big.2020.0051`
- "Sperm whale algorithm: An effective metaheuristic algorithm for production optimization problems" `https://www.sciencedirect.com/science/article/pii/S1875510016300014`

Random emoji not related any other researchers' work: 

Note: There is no code required for this problem. However, I will give *an additional 5 points of credit* for correctly coded implementations.

Question 3: More extra-credit (15 points)

Your choice: VNS, GLS, or Tabu Search. Using the Python code as a base, implement VNS, GLS, or Tabu Search to solve the knapsack problem.

Apply the technique to the random problem instance and determine the best solution and objective value using your revised algorithm.