

Assignment One Report- Sian Gooding

Simulated Annealing

What is Annealing?

Annealing is a heating process where a material is heated to a specific temperature and then allowed to cool slowly, if the material is cooled slowly enough then the atoms are allowed to rest in the most stable orientation which produces a crystalline structure- this structure is an energy-minimizing state.

Simulated annealing is a probabilistic technique for approximating the global optimum of a given function. Cooling in simulated annealing is represented as the decrease in the probability of accepting a worse solution as it explores the search space.

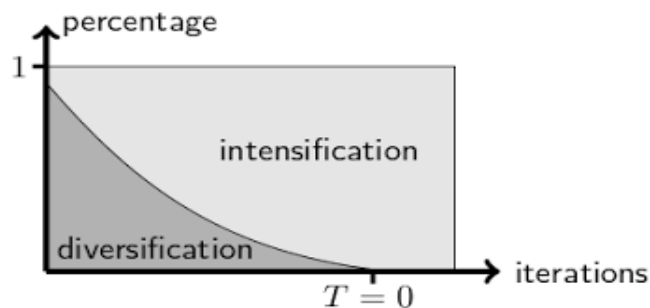


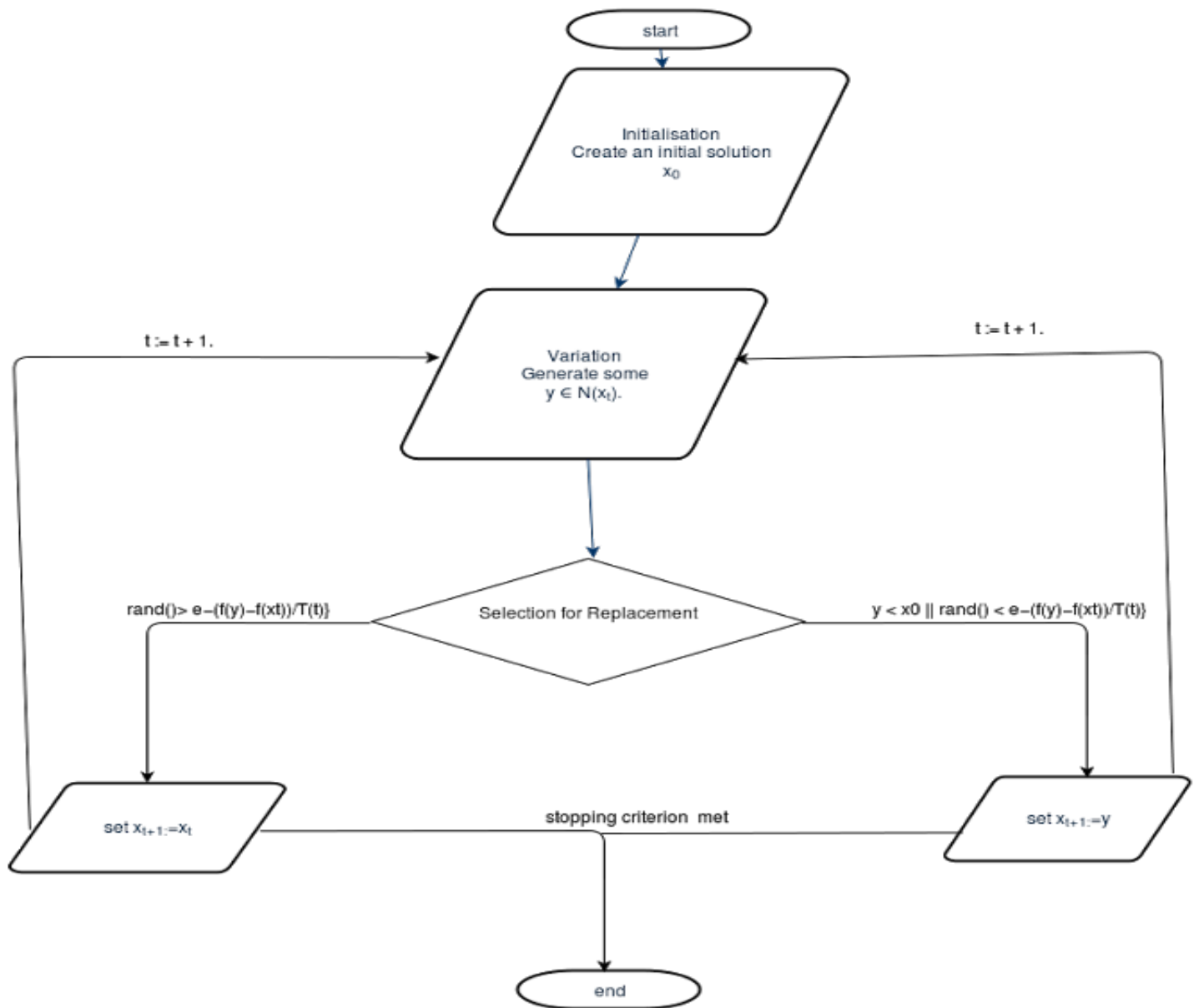
Image from Christine Zarges lecture slide 10

For $T=0$ we have pure hill climbing.

Pseudocode

1. **Initialisation:** Generate an initial solution S . Set $t:=0$.
2. **Variation:** Generate some $y \in N(x_t)$.
3. **Selection for Replacement:**
With probability $\min \{1, e^{-(f(y)-f(x_t))/T(t)}\}$,
set $x_{t+1} := y$ else $x_{t+1} := x_t$.
4. **Stopping**
Increment t ($t := t + 1$). If stopping condition not met then continue at line 2.

Simulated Annealing Flowchart



My implementation of Simulated Annealing

To implement simulated annealing, I adapted the simple hill climbing algorithm.

Parameter Tuning

Even though a slow annealing schedule delivers good solutions I had to compromise due to time constraints.

I chose to use a fixed annealing schedule $T_{i+1} = c \cdot T_i$ as typical values are $c \in [0.9, 0.999]$ I chose 0.999 as during parameter tuning this value was optimum.

In order to set the initial temperature T_0 I generated a number of random solutions in between 1-200 and tested which produced the best results.

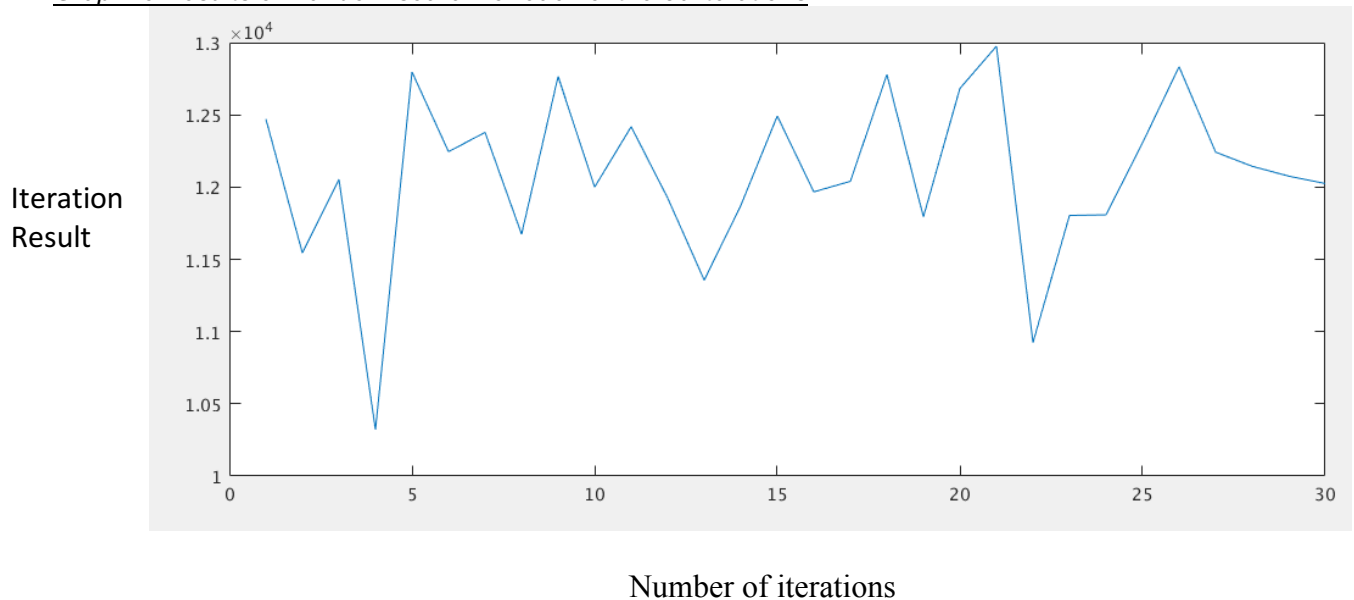
Results

Results obtained for 30 runs (1000 iterations)

	Mean	SD	Max Distance	Min Distance
Randomized Search	12090.73	574.39	12975	10321
Hill Climbing	12196.80	1586.8	14659	9166
Simulated Annealing	7751.30	311.02	8401	7080

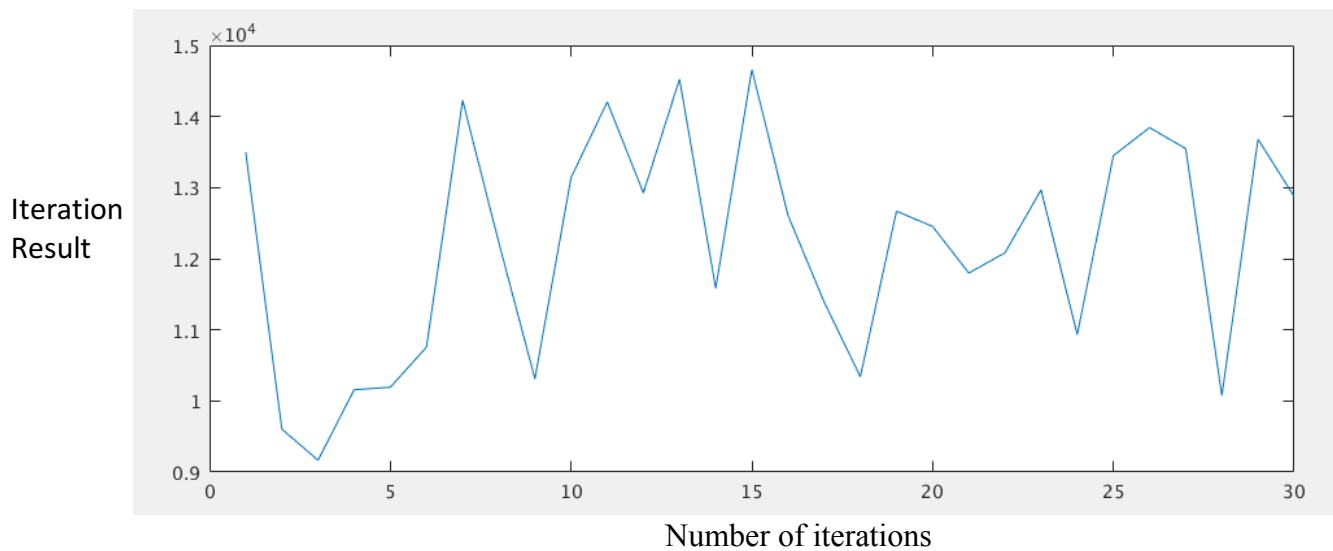
Looking at the results it is clear that simulated annealing is superior to randomized search and hill climbing algorithms as it consistently gets much closer to the optimum which was expected given the random nature of the other two algorithms. The mean result for randomized search and hill climbing is similar and the largest standard deviation is for hill climbing.

Graph for results of Random search for each of the 30 iterations



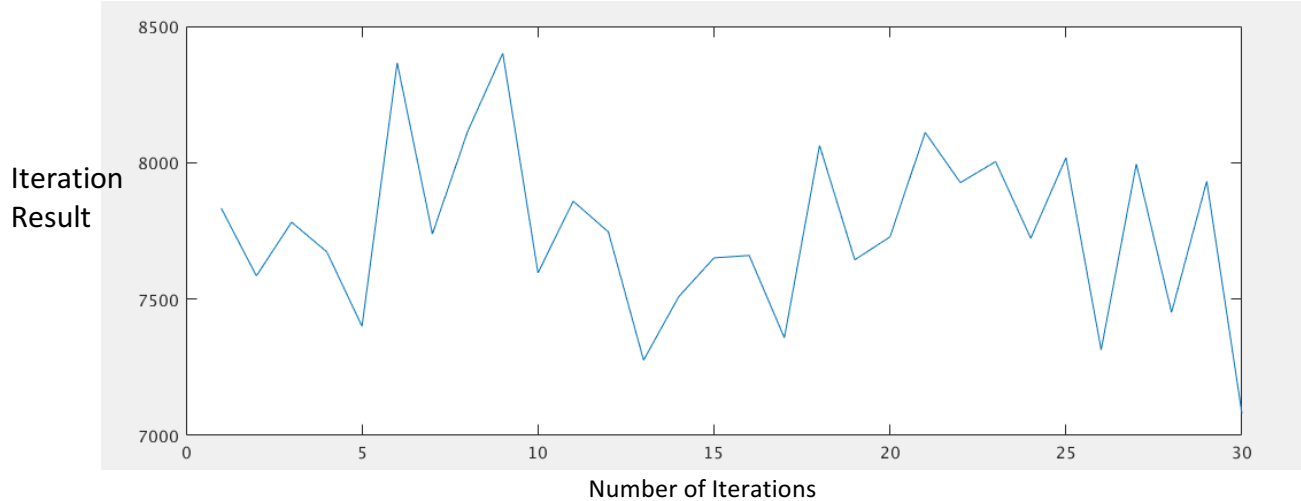
As this graph shows there are big variations in the performance of randomised search, here the graph shows the best distance found over each of the 30 iterations.

Graph of results for Hill Climbing algorithm over 30 iterations.



The best value obtained by hill climbing was 9166 and the worst case was 14659, hill climbing has the largest standard deviation because of the variation of good and bad results each iteration produced.

Graph of results for Hill Climbing algorithm over 30 iterations.



Here it is clear by the result scale that the results from simulated annealing were much closer to the optimum, the maximum distance produced by a run of simulated annealing was 8401 which is lower than the best results from the other two algorithms.