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Algorithm A: Genetic Algorithm (GA)

Algorithm B: Particle Swarm Optimisation (PS)

Description of enhancement of Algorithm A:

The biggest improvement to my implementation was the use of diversity mechanisms, especially mutation.

I implemented 6 different mutation operators including RSM (Reverse Sequence), PSM (Partial Shuffle), THROAS, THRORS, random swap, and full shuffle which helped maintain genetic diversity within the population. Inspired by [(Otman, 2012)](https://doi.org/10.48550/arXiv.1203.3099), my algorithm randomly chooses the mutation to perform, with each mutation operator being weighted according to how good I found it to be at promoting genetic diversity. Additionally, the weight of the full-shuffle mutation scales exponentially with the number of iterations since the last incumbent solution. It follows the curve: , which increases gradually from 1 to 8 throughout roughly 1000 iterations. This allows the algorithm to vary how harshly it promotes diversity. I experimented with a few cross-over operators, in particular OX, and SCX, however, I found the OX operator to be the most successful. I tried to vary the crossover operator during runtime but found that SCX, while quicker at converging, led to sub-optimal tours, which is likely due to its close resemblance to the nearest-neighbour algorithm.

I switched from roulette selection to tournament selection which improved performance and led to higher quality tours. I implemented the 2-opt local-optimisation algorithm and chose to treat it as a mutation. It randomly occurs and can be thought of as two parent individuals randomly spawning a genius child individual, which helps the algorithm converge.

I found that running 2-opt fully resulted in lower genetic diversity, and instead, only run 10 passes of 2-opt per call.

To improve convergence, I implemented random extinctions which occur after a threshold of iterations, and purge between 20-40% of the least-fit individuals in the population. Additionally, as per [(Eremeev, 2021)](https://doi.org/10.1145/3449726.3462729), I added random classical restarts, which trigger after a threshold iteration, and if the current iteration number > 2 × iteration of the incumbent solution.

As with PSO, I tried to initialise the individuals in my population with tours formed using nearest neighbour instead of fully random, however, I found this to hurt the genetic diversity of the population. My implementation outperformed the basic version by roughly a 5-10% reduction on city sets smaller than 48, and between 25-97% on city sets larger than 48.

Description of enhancement of Algorithm B:

The first modification I chose to make was implementing a different velocity function to remove the time complexity of bubble-sort. I did this by implementing a velocity function with non-consecutive swaps (permutation), which drastically improved the performance of the algorithm. I experimented with different topologies of PSO and found that the star topology (global best) [(Shami, 2022)](http://dx.doi.org/10.1109/ACCESS.2022.3142859) was the most efficient and consistent at finding good solutions.

Upon testing different parameter configurations, I found that by bounding the epsilon proximity parameter between 0.8 and 1, the algorithm was more consistent at finding good solutions. By adding an annealing factor to the inertia (theta) [(Shami, 2022)](http://dx.doi.org/10.1109/ACCESS.2022.3142859), and scaling it exponentially from 1 down to 0, particles were less likely to leave a local minima’s area, resulting in better tours. I also implemented velocity normalisation which triggers if . This means the complexity/length of each velocity can be contained, avoiding velocity explosion [(Shami, 2022)](http://dx.doi.org/10.1109/ACCESS.2022.3142859), and improving performance.

While all these improvements helped with performance, the quality of the tours was lacking. I decided to try using nearest-neighbour for initialising particle tours, which was achieved by randomly generating a partial tour (of length 2-3), and then completing it using nearest-neighbour. This led to significant tour quality improvements and by integrating the 2-opt local optimisation algorithm [(Croes, 1958)](https://doi.org/10.1287/opre.6.6.791) [(Uddin et al.)](https://doi.org/10.3390/app13127339), my PSO algorithm saw near-optimal performance.

One drawback to this was that particles often got stuck in local optima and failed to escape, which was likely caused by the choice of topology. I decided to get a bit creative and implemented dazing (this might already exist, but I couldn’t find any relevant literature). To put simply, the idea behind dazing is to avoid particles tending towards the same global optima. In practice, if a particle hasn’t improved upon its personal best in a certain number of iterations, it has a small chance of getting dazed where its position is randomly reset, velocity is set to 0, and it is blinded (social velocity = 0) for a duration of 10 iterations. This adds some diversity to the algorithm and avoids premature convergence.

Similarly, extinction events were implemented to escape local optima which resulted in higher-quality tours.

Overall, my PSO algorithm outperformed the basic implementation by a consistent reduction of 40-70% and in some cases up to 99.7%. (Each basic algorithm was run 5 times (60s each) on each city set; the median time of each run was compared to the enhanced algorithm’s best overall solution)

***DESCRIPTION OF ALGORITHM ONLY IF THE ALGORITHM IS NOT COVERED IN LECTURES***

Description of *non-standard* Algorithm A:

Description of *non-standard* Algorithm B: