Comparison of Simulated Annealing and Genetic Algorithm for the Traveling Salesman Problem

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1 Introduction

The Traveling Salesman Problem (TSP) is a classical combinatorial optimization problem that aims to find the shortest possible route visiting a set of cities exactly once and returning to the starting city. Due to its NP-hard nature, heuristic approaches such as Simulated Annealing (SA) and Genetic Algorithm (GA) are often employed to find approximate solutions. This project presents a comparison between SA and GA using different TSP datasets.

2 Problem Definition

The goal of this project is to minimize the total travel distance for different TSP instances. The datasets used in this study include the following:

- `a280.tsp`
- `bayg29.tsp`
- `bays29.tsp`
- `brazil58.tsp`
- `ch130.tsp`
- `br17.atsp`
- `ft53.atsp`
- `kro124p.atsp`
- `p43.atsp`
- `ry48p.atsp`

The performance of both algorithms is evaluated in terms of the total distance found and the computation time required.

3 Methodology

3.1 Simulated Annealing

Simulated Annealing is a probabilistic technique that approximates the global optimum of a function. In this approach, an initial random solution is generated, and iteratively improved through random swaps of city positions. The acceptance of a worse solution is controlled by a probability function based on the temperature, which gradually decreases following a cooling schedule. Key parameters include:

- **Initial Temperature**: 10000.0
- **Cooling Rate**: 0.995
- **Max Iterations**: 10000

3.2 Genetic Algorithm

The Genetic Algorithm is a population-based approach inspired by natural selection. An initial random population of candidate solutions is generated and evolved through selection, crossover, and mutation. Key parameters include:

- **Population Size**: 50
- **Mutation Rate**: 0.1
- **Max Iterations**: 10000

The GA involves fitness calculation, tournament selection for parents, one-point crossover to generate offspring, and random mutation.

4 Experimental Results

The results of applying Simulated Annealing and Genetic Algorithm to the TSP instances are summarized in Table 1.

Dataset	SA Total Distance	SA Time (s)	GA Total Distance	GA Time (s)
a280.tsp	2808	0.007	29732	0.448
bayg29.tsp	1922	0.003	3284	0.069
bays29.tsp	2474	0.001	4080	0.085
brazil58.tsp	31680	0.002	85559	0.129
ch130.tsp	14026	0.004	39841	0.237
br17.atsp	42	0.001	54	0.063
ft53.atsp	10348	0.002	19734	0.121
kro124p.atsp	66292	0.003	158651	0.188
p43.atsp	5716	0.002	6210	0.107
ry48p.atsp	18660	0.002	37405	0.114

Table 1: Comparison of Simulated Annealing and Genetic Algorithm on different TSP datasets

5 Analysis

The experimental results reveal that Simulated Annealing consistently finds shorter routes compared to the Genetic Algorithm for each dataset. Moreover, SA is significantly faster in all cases. The advantage of SA may be attributed to its straightforward iterative improvement mechanism, while GA's reliance on crossover and mutation can introduce randomness that may slow convergence and result in suboptimal solutions.

Genetic Algorithm, while useful in exploring a broader solution space, faces challenges due to the stochastic nature of mutation and crossover, which might lead to local optima without achieving better solutions. On the other hand, Simulated Annealing's gradual cooling mechanism allows for a more focused search, which helps in minimizing the overall travel distance more efficiently.

6 Conclusion

This study demonstrates that Simulated Annealing outperforms the Genetic Algorithm in both solution quality and computational efficiency for the tested TSP datasets. Future work may involve tuning the Genetic Algorithm parameters or exploring hybrid approaches that combine the strengths of both algorithms to achieve better performance.