Search and Optimization on TSP, Frozen Lake

AI Assignment 2

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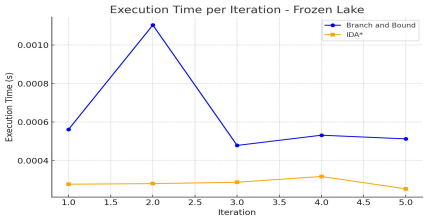
Problem Setup & Heuristics

- **Environments**:
  - 🔷 `gym_TSP`: For HC & SA
  - ❄️ `FrozenLake` : For BnB & IDA*
- **Algorithms**:
  - Branch and Bound (BnB)
  - Iterative Deepening A* (IDA*)
  - Hill Climbing (HC)
  - Simulated Annealing (SA)
- **Heuristics Used**:
  - FrozenLake : Manhattan Distance to goal
  - TSP: Total path cost from permutation of cities
- **Evaluation Metrics**:
  - Reward = `-1 * Distance/Steps`
  - Time (sec)
  - Convergence Point (iterations)

🔎 Branch and Bound vs IDA*

Environment: Frozen Lake
Tested over **5 runs**, with **τ = 10 mins**

📈 **Graph**: Execution time across iterations for Branch and Bound vs IDA* on Frozen Lake



bnb_frozenlake.gif

ida_frozenlake.gif

🧠 **Observation**:

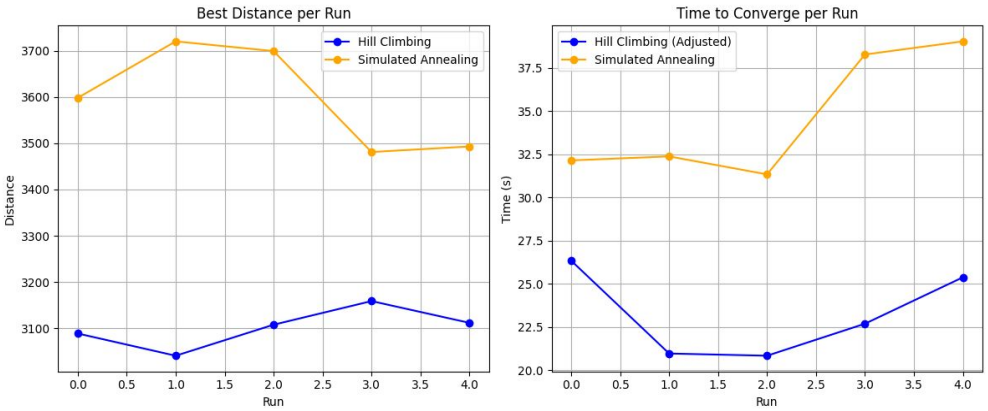
- BnB is slightly **higher average time** due to one outlier run but memory intensive because it maintains an explicit search tree.
- IDA* is **faster on average** and **more consistent**, but **uses less memory** due to its depth-first nature.

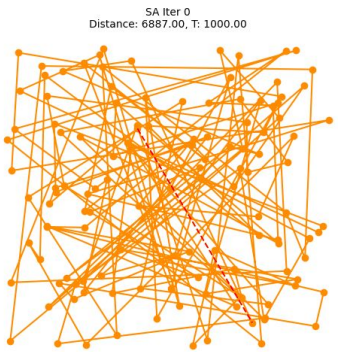
Iteration	BnB Execution Time (s)	IDA* Execution Time (s)
1	0.000562	0.000278
2	0.001103	0.000281
3	0.000479	0.000288
4	0.000532	0.000318
5	0.000513	0.000254

Metric	Branch and Bound (Avg)	IDA* (Avg)
Time (FL)	0.0006378 s	0.0002838 s
Success Rate	5/5	5/5

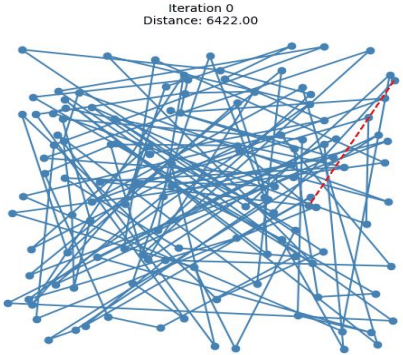
🧭 Hill Climbing vs Simulated Annealing

Environment: TSP (126 cities) Tested over **5 runs**, with **τ = 10 mins**





sa_tsp.gif



hc_tsp.gif

Metric	Hill Climbing (Avg)	Simulated Annealing (Avg)
Time	23.2s	34.6s
Best Distance	3101.8	3598.2

🧠 **Observation**:

- **HC** is faster due to stuck on local minima it restarts which makes it slower than SA but greedy
- **SA** is slower but more exploratory — avoids premature convergence.
- Tradeoff: SA takes more time but generally finds better-quality paths.

⚖️Algorithm Comparison

Algorithm	Time Taken	Converge Pt	Success Rate	Strength
BnB	Low	Fast	High	Guaranteed optimal if time
IDA*	Medium	Medium	Good	Low memory, longer path
HC	High	Early	Moderate	Fast convergence
SA	Medium	Late	High	Better global optima

🎯 **Takeaway**:
Choice of algorithm depends on:

- Problem complexity
- Trade-off: time ⏱️ vs solution quality 🧠

Conclusion & GitHub Link

Key Learnings:

- No single algorithm wins everywhere
- Heuristics deeply affect performance
- SA and BnB give better final results at higher cost

- **GitHub Repo**: 🔗 *https://github.com/Ashantfet/AI_Optimation_search*

- **Thank You!** 🎉