TEAM : DELTA6

TRAFFIC-AWARE SINGLE-DRONE DELIVERY ROUTE OPTIMIZATION

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MOTIVATION

- Drone delivery must minimize travel time, not just distance
- Urban airspace introduces air space congestion, but thankfully we do not have roads or traffic signals restricting our paths!
- Thus, route planning becomes an AI optimization problem

PROBLEM DEFINITION

Objective

Find the fastest closed delivery route, assuming presence of traffic at each edge, starting and ending at N0.

- Nodes: N0, N1, ..., N(n-1)
- State space: Permutations of nodes
- Cost: Traffic-adjusted travel time

TRAFFIC-AWARE COST MODEL

Each node has congestion factor $c_i \in [1, 3]$.
Edge congestion:

$$c_{ij} = \frac{c_i + c_j}{2}$$

Travel time:

$$t_{ij} = d_{ij} \cdot c_{ij}$$

ALGORITHMS USED

- Deterministic Hill Climbing
- Stochastic Hill Climbing

DETERMINISTIC HILL CLMIBING

- Local search algorithm; improves a solution iteratively based on a fixed objective function
- The algorithm takes the set of all adjacent nodes(all neighbours of the current node)
- Chooses best improving local neighbour = makes local optimal choice. Hence it is a Greedy algorithm.
- The algorithm stops if no better neighbour exists.
- Fast convergence to a result, that may or may not be optimal
- It does not maintain a search tree or allow backtracking. Only the current node is stored.
- Computationally efficient per iteration but the algorithm may require evaluation of many neighbours.

STOCHASTIC HILL CLMIBING

- Local Search Algorithm that optimises objective function.
- Does not evaluate all the neighbours; saves space.
- Neighbour selected at random - introduces stochasticity(randomness) in choice of neighbours ; helps avoid shallow local maxima or plateaus.
- P(selecting neighbour) biased towards higher improvement.
- Can get stuck at a local maxima in a rugged search space.
- Accepts any improvement.
- Better exploration.
- It is simple and more memory efficient.

EXPERIMENTAL SET-UP

- 120 delivery nodes
- Congestion range: [1,3]; 1 - least/no congestion, 3 - heavy congestion.
- Multiple runs per algorithm
- Controlled randomness of node positions - seed set to 46656. If the seed value remains the same, then the same set of random numbers will be generated in every iteration.
- Base air speed of drone was set to 50kmph(Multirotor drones have no stall speed, since hovering requires 0 m/s. Fixed Wing drones have a stall speeds between: 36-90kmph)
- Arrows used to indicate path taken
- Colour grading used on the edge connecting any two nodes to indicate the level of traffic congestion.

NODE POSITION AND GRAPH STRUCTURE FOR DETERMINISTIC HILL CLIMBING

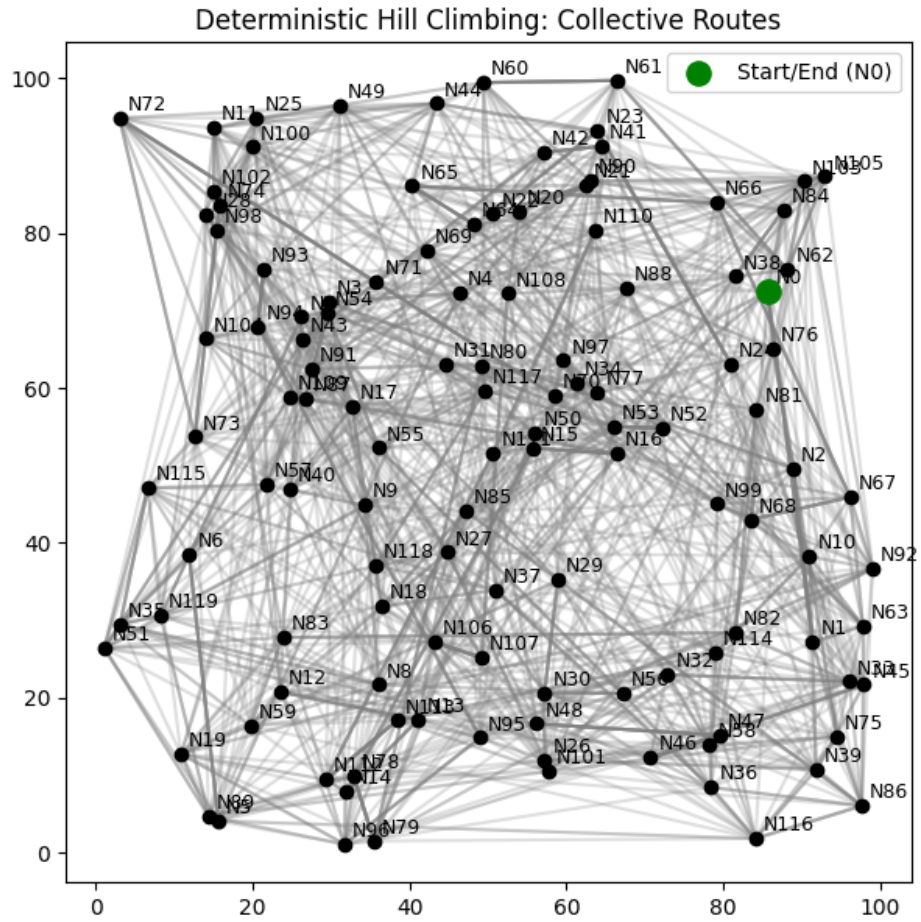


Figure: Collective route for deterministic hill climbing algorithm

NODE POSITION AND GRAPH STRUCTURE FOR STOCHASTIC HILL CLIMBING

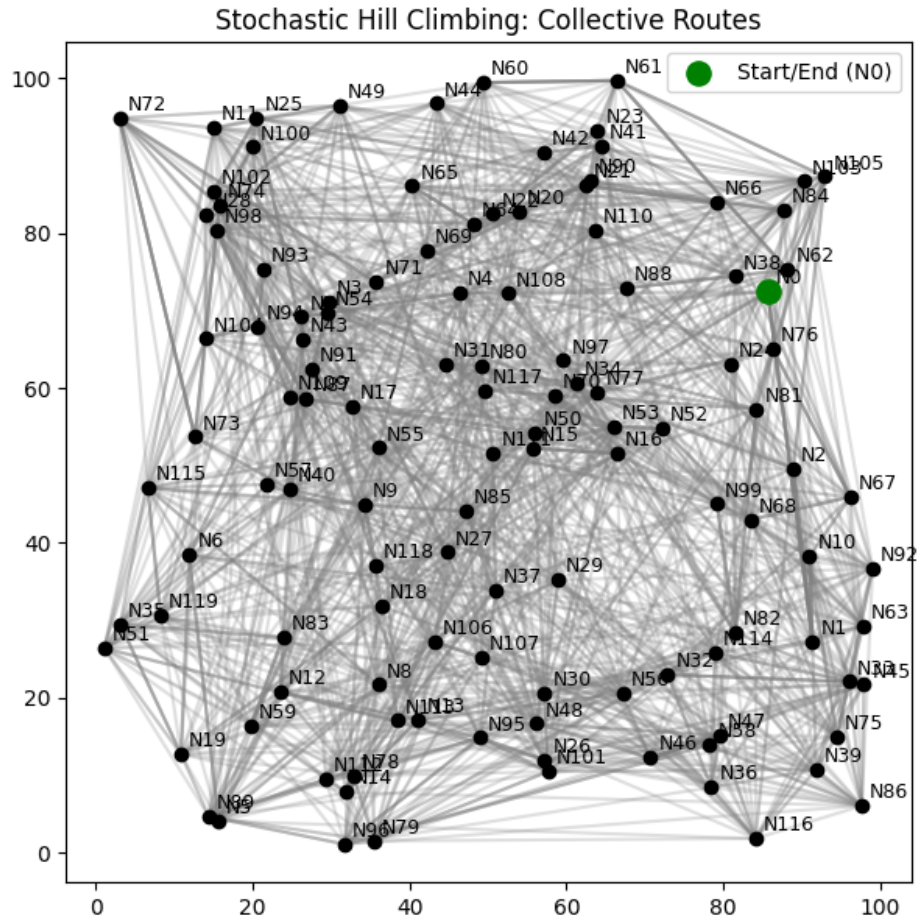
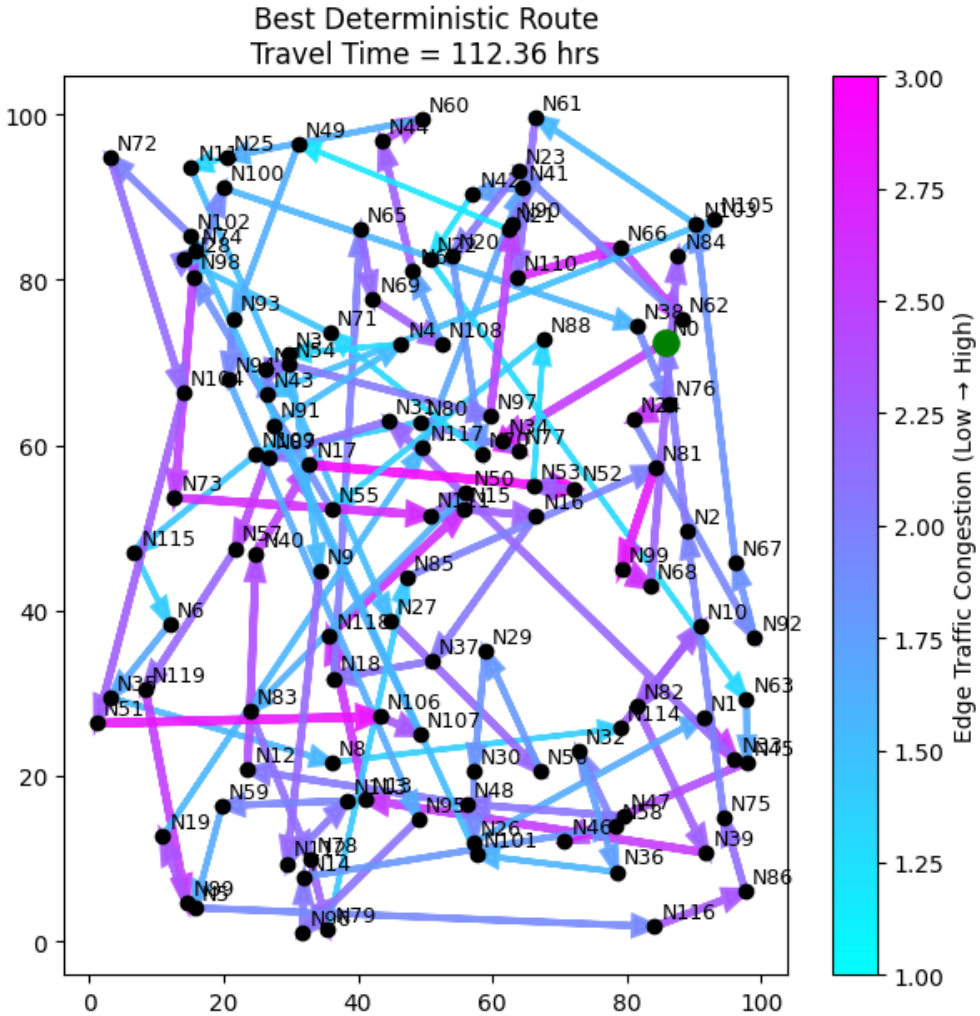


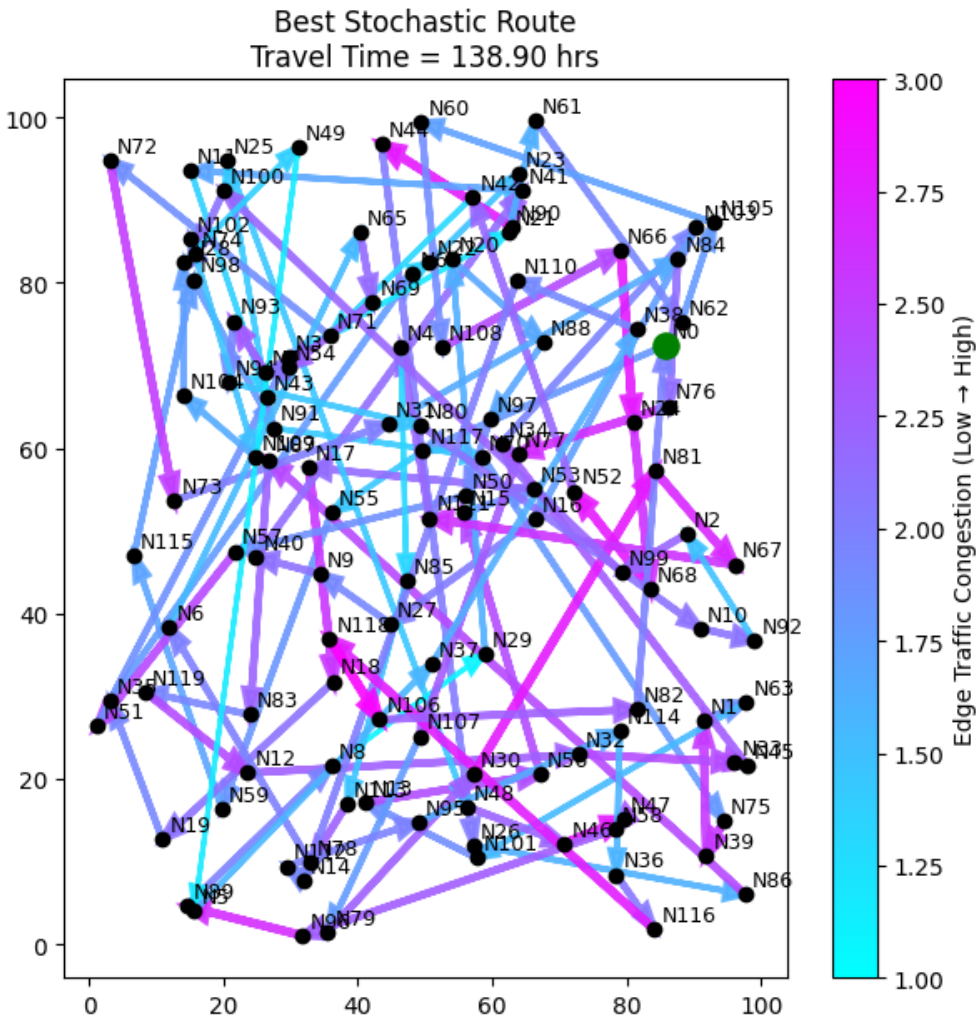
Figure: Collective route for stochastic hill climbing algorithm

DETERMINISTIC ROUTE



Test run travel time: 112.36 hours

STOCHASTIC ROUTE



Test run travel time: 138.90 hours

CONVERGENCE RATE COMPARISON : D-HC vs S-HC

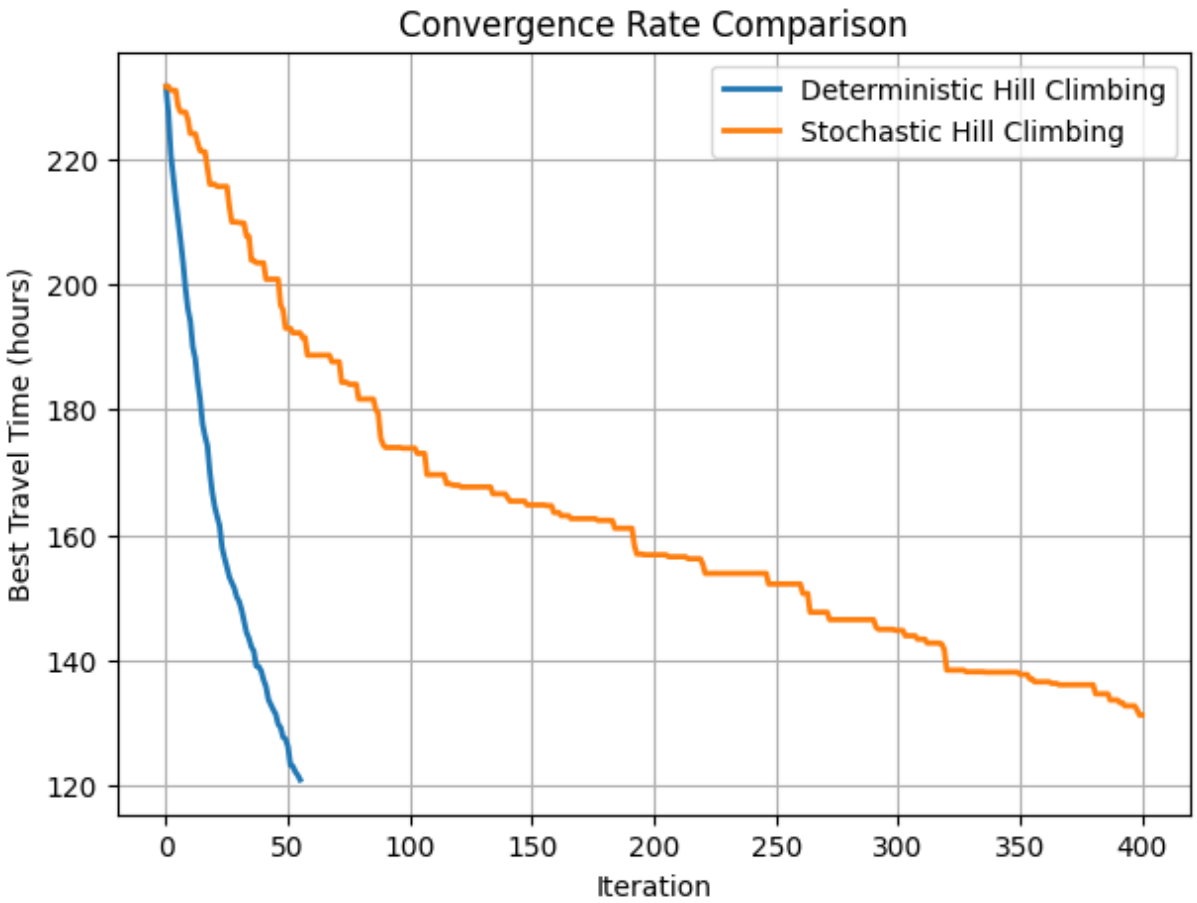


Figure: Example test run with 400 iterations

RESULTS

- Stochastic Hill Climbing explores more routes.
- Deterministic Hill Climbing converges faster.
- The optimal algorithm to be used, and the optimal path to be taken are, however, completely random. They change with each iteration, based on node location and traffic on each edge.

FURTHER ADVANCEMENTS

- We can use multiple drones to build an entire delivery system. Each drone can have different base speeds, and a different altitude of operation to reduce traffic congestion, but let us be mindful of the fact that expecting a civilian drone to operate at beyond 20,000 ft is too unrealistic and might cause restrictions to military operations.
- In the supposed delivery system, say we have more 1000 or 10000 routes, what do we do then?
- In such a case we can classify the nodes based on region. If distance between any two given nodes is greater than the distance between the distances between any two points lying in the same cluster, the point farthest away from the given cluster will be removed from the cluster and will be added to the nearest cluster. If no cluster is close to it, this node will be treated as an isolated point and a single drone will be specifically arranged to cater to its interests.

FURTHER ADVANCEMENTS CONTD.

- The maximum number of isolated points, in any given iteration, can be 1 and not more than that, because every node will certainly fall under the jurisdiction of one area/region.
- Moreover, to reduce traffic congestion we will be operating each drone at a different altitude with a maximum altitude difference between drones of each class being atleast 20 feet and atmost 500 feet.
- In short, every class of drone operates within a certain ALTITUDE BANDWIDTH.
- So, for example, 50 drones catering to 5 different clusters will operate at 5 different altitudes. Drones of class 1 will operate at 1000ft, Drones of class 2 at 1100ft, and so on.
- This will make the delivery system more efficient despite the impending problem of deliberate traffic congestion.

CONCLUSION

- A traffic-aware model adds to the realism in describing such real world problems.
- Hill climbing is effective particularly for local search
- Visualization of best path for each algorithm and the comparison of convergence rate of both Deterministic and Stochastic Hill Climbing algorithms explains algorithm behaviour.
- Algorithm efficiency depends on a number of real world factors, in this case, traffic congestion and distance between two adjacent nodes, at the very least. There could be more factors but these two are the most apparent!

THANK YOU!!