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Simulated Annealing Algorithm for Solving the Matching and Dispatching Problem in Dynamic Large-Scale Settings

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Introduction

Ridesourcing services: Scope definition

Ridesourcing services connect, match, and dispatch operating vehicles to waiting requests within a very short duration in real-time settings.

Main considerations:

1. Matching & Dispatching
2. Rebalancing
3. Dynamic travel time estimation

The objective is to put forward a flexible method that can provide good vehicle-request matching solutions in dynamic settings. The focus is to serve as many requests as possible with a constant fleet size without largely compromising the cumulative waiting time of system users. The method is tested in a simulation framework and the results are compared to more standard nearest-vehicle matching solutions.

Model

The Matching and dispatching problem

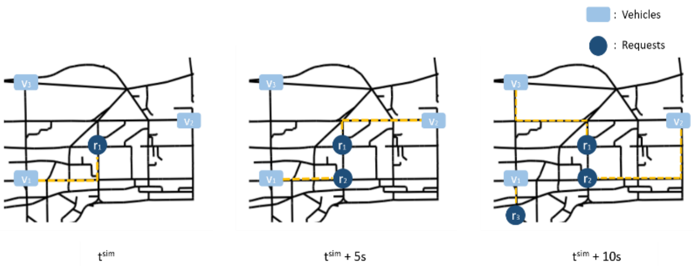
Objectives:

- Maximization of the number of served requests.
- Minimization of the waiting time for all potential passengers.
- Equal distribution of workload over the different vehicles.

Constraints:

- Maximum **capacity** of operating vehicles **C**.
- Maximum allowable **detour** for passengers (shared trips) **Ω**.
- Maximum **waiting time** of potential passengers **Δ**.

Batch vs instantaneous assignment:
Accumulating requests during a given time step of the simulation time t^{sim} may improve the assignment solution.

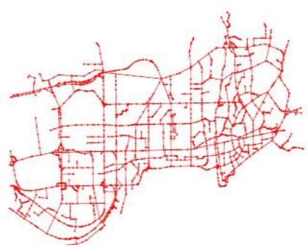


Simulation Framework

Shenzhen network [1]

Main Parameters:

Simulation settings	
Shenzhen CBD area (km^2)	140
Vehicle capacity C	2
Allowable detour Ω (%)	0.2
Waiting time Δ (minutes)	10
Requests (thousand)	8



Solution Approach

Building an initial solution

The first insight into solving the assignment problem between vehicles and requests is to start by building the **bipartite matching (BM)** graph, and then to proceed with solving a linear assignment problem using the **Hungarian algorithm**. The objective is to minimize the total distance traveled while exclusively assigning each request to a single Transport network Company (TNC) vehicle for shared and unshared trips.

Cost matrix

	r1	r2	r3	r4
v1	INF	2.3	5.4	INF
v2	9.5	INF	6.5	INF
v3	3.2	INF	6.7	4.2
v4	INF	6.5	8.2	INF
v5	5.2	2.2	5.6	INF
v6	INF	INF	INF	INF

Computation of cost

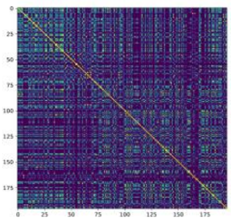
$$c_{ij} = t(v_i^c, r_j^o) + t(r_j^o, r_j^d)$$

$$c_{ij'} = t(v_i^c, r_{j'}^o) + t(r_{j'}^o, r_j^d) + t(r_j^d, r_{j'}^d)$$

$$c_{ij'} = t(v_i^c, r_{j'}^o) + t(r_{j'}^o, r_{j'}^d) + t(r_{j'}^d, r_j^d)$$

Reoptimization

Greedy Insertion Heuristic (GIH) [2]
A long-sighted approach would require to account for future planned vehicle movements. From this point stems the need for consideration of all possible assignments and selecting the one with the lowest incurred cost. To speed up the process, it is possible to build the similarity matrix for waiting requests and then employ **spectral clustering**.

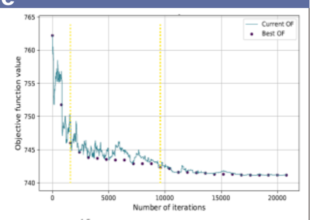


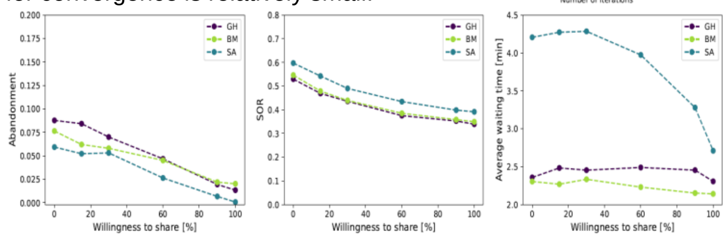
Local Search and Simulated Annealing (SA)
It accepts deteriorating solutions in attempt to accommodate more requests. This method compromises between available time for assignment and neighborhood exploration.

Results

Abandonment, Seat Occupancy Rate (SOR), and waiting time

Compared to **BM** and Greedy Heuristic **GH** (nearest-vehicle assignment), the method allows a better service and an improved utilization of available TNCs (500) at the expense of an increased waiting time. The number of iterations for convergence is relatively small.





References

[1] Caio Vitor Beojone and Nikolas Geroliminis. On the ineciency of ride-sourcing services towards urban congestion". In: (2020). arXiv: 2007.00980 [physics.soc-ph].

[2] Jaeyoung Jung, R. Jayakrishnan, and Ji Park. Dynamic shared-taxi dispatch algorithm with hybrid simulated annealing. Computer-Aided Civil and Infrastructure Engineering, 31, 06 2015.