Enabling E-Mobility: One Way, Return, and with Loading Stations

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TAKING INTO ACCOUNT LOADING STATIONS

A loading station (LS) is a node \( e \in V \), that loads up a full battery \( \mathcal{B}_0 \), whenever it is visited. The set of all LSs is called \( L \subseteq V \).

GOAL Compute paths from \( s \in V \) to \( t \in V \) with minimal number of necessary recharging events.

APPROACH Build auxiliary graph \( Q \) upon loading stations in a preprocessing step.

\[
Q = (E', \{L \\}=:m)
\]

\( L \) is a set of LSs

\( \forall (e, f) \in E' \forall (g, h) \in L \Rightarrow (e, f) \text{ is reachable from } (g, h) \)

A path in \( Q \) is constructible from \( e \in V \), it cannot be extended further.

QUERY ANSWERING

1. Compute \( \mathcal{E}_{L} \): L set of reachable LSs from \( s \in V \)

\( \text{Time}(\mathcal{E}_{L}(s) = m) \)

2. Compute \( \mathcal{E}_{L} \): L set of LSs from \( (g, h) \) can be reached from \( s \in V \)

\( \text{Time}(\mathcal{E}_{L}(s) = m) \)

3. Run BFS from \( (g, h) \in Q \) until the first node in \( L \) is reached

\( \text{Time}(\mathcal{E}_{L}(s) = m) \)

4. Backtrack respective path

\( \text{Time}(\mathcal{E}_{L}(s) = m) \)

Total run time \( \text{Time}(\mathcal{E}_{L}(s) = m) \)

MULTI-CRITERIA OBJECTIVES

Natural Goals

1. Find the energy-optimal path amongst all paths at most 10% longer/better than the shortest/quickest path

2. Find the shortest/quickest energy-feasible path

3. Find the shortest/quickest feasible path with at most 1 recharging events

4. Find a feasible path with a minimum number of recharging events and bounded distance/time.

Instance-based lower bounds and heuristic results for the number of LSs necessary to achieve the goals ERC and ECC in the graph of Germany.

Approach for 1. & 2.
Label setting (realization) (LSR) still works if cost or resource constraints are functional.

Adapt speed-up technique Contraction Hierarchies (CH) to decrease query times for LSC.

Shorterm feasible paths between loading stations are necessary under the choice of \( f \) and \( l \) (pre)precomputation possible, build layered graph

Augment layered graph on query time with proper edges from \( f \) to \( t \) (restituted by two local LSCs) 

where \( \mathcal{E}_{L} \) can run locally the optimal path

OVERALL GOAL

develop algorithmic tools to solve fundamental problems in E-Mobility in order to make EVs competitive to conventional cars