Shortest Path and Scheduling with Driving Hours and Parking Availability Constraints

Filipe Vital
Petros Ioannou
Motivation

Too many trucks, not enough parking spaces...

- Many drivers report issues to find truck parking at night.
- Less than 50% of truck stops report operating overcapacity at night.

Too many trucks going for the same rest areas at the same time!!!
Previous Work
• Working hours regulations
• Parking restricted to certain locations
• Scheduling (fixed path) + Parking availability
• Routing (choose order of clients)

Our Objective
• Include parking availability
• Optimize path between clients
Problem

Objective
Minimize Trip Duration

- Send a single truck from A to B;
- Location B has 1 or more delivery time-windows;
- Can stop only at rest areas;
- Schedule must comply with the regulation;
- Rest areas with a scheduled stop must be available at the time of arrival.
Constraints

Structural
- Network Topology
- Departure time

Client Time-windows
- Restrict arrival time

Regulation
- Elapsed time
- Accumulated driving time
- Minimum rest duration

Parking Availability Time-windows
- If stopping, restrict arrival time
- If stopping, must rest

Required Visit/Stop

Optional Visit/Stop
Parking Availability

Time-windows
- start when the parking lot is expected to become available
- end when the parking lot is expected to become full
- matter only when the driver needs to stop
- early arrival is not allowed.
Shortest Path with Resource Constraints

Resources
- current time ($\eta^0$)
- elapsed time since trip start ($\eta^s$)
- elapsed time since last break ($\eta^b$)
- elapsed time since last daily rest ($\eta^r$)
- accumulated driving time since last daily rest ($\psi^r$)
- accumulated on-duty time since last weekly rest ($\psi^w$)
# Resource Extension Functions

<table>
<thead>
<tr>
<th></th>
<th>$f^d$</th>
<th>$f^s$</th>
<th>$f^b$</th>
<th>$f^r$</th>
<th>$f^w$</th>
<th>$f^0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\eta}_{k+1}^0$ =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\hat{\eta}_{k+1}^s$ =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\hat{\eta}_{k+1}^b$ =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\hat{\psi}_{k+1}^r$ =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\hat{\psi}_{k+1}^w$ =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

d: Driving, s: Service, b: Break, r: Daily rest, w: Weekly rest, 0: Departure
Label Correcting Algorithm

Problem and Method Parameters

Label Correcting Algorithm

Initial Condition

Dominance Criteria

Search Method

Regulations

Network

Expansion Criteria

UB Estimator

LB Estimator

Add Label

Empty?

Get Next Label

Expand Partial Solution

Destination?

LB check

Optimal

Stop

Open Set

update upstream labels

Not optimal

Dominance Check

Create Labels
Label Correcting Algorithm

- Label Treatment Order
- Decisions to Test
- Label Improvement
- A*
- Dominance Check
Measurements
- Alternative route usage
- Average driving times
- Average trip duration

Main route

Alternative route
Results – Single Client

- **Time-Windows = Wide**
  - Alt. Route Usage
  - Travel Speed on Alternative Routes (km/h)
    - 1%
    - 0%
    - 0%

- **Time-Windows = Medium**
  - Alt. Route Usage
  - Travel Speed on Alternative Routes (km/h)
    - 9%
    - 2%
    - 0%

- **Time-Windows = Narrow**
  - Alt. Route Usage
  - Travel Speed on Alternative Routes (km/h)
    - 98%
    - 60%
    - 10%

**Average Driving Time (h)**

- **Alternative Routes Travel Speed (km/h)**
  - 75
  - 70
  - 65
  - Only Main Route

**Average Trip Duration (h)**

- **Alternative Routes Travel Speed (km/h)**
  - 75
  - 70
  - 65
  - Only Main Route

University of Southern California
Results – Two Clients

- Time-Window = Wide
  - 28% Alt. Route Usage
  - Travel Speed on Alternative Routes (km/h)

- Time-Window = Medium
  - 99% Alt. Route Usage
  - 65% Travel Speed on Alternative Routes (km/h)

- Time-Window = Narrow
  - 100% Alt. Route Usage
  - 75, 70, 65 Travel Speed on Alternative Routes (km/h)
Conclusion

- **Parking restrictions** greatly affect the minimum cost **path** and schedule between two locations;
- Under limited parking availability, it is cost-effective to consider **alternative paths**;
- The label correcting method presented generates paths and schedules that are **feasible in practice**;
- It can be used as a **post-processing** step to refine the path for a given route or directly integrated in a **vehicle routing algorithm**.
Future Work

Thank You!

- Stochastic Parking Availability
- Extend to Battery Electric Trucks (energy consumption, charging stations)
- Include speed optimization
- Include time-dependent travel times
- Multiple vehicles routing
- Vehicle platooning