Stochastic and Dynamic Patient Transportation

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EULOG, Salzburg, 11.05.2012
Overview

1. Introduction
2. Solution Approach
3. Dynamic Programming Approach
4. Computational Results
5. Summary and Outlook
Emergency Medical Service

- Patient Transportation Arbeiter Samariterbund Wien (ASB)
- 800-1000 transportation daily requests
- Fleet of about 120 vehicles
- Two dispatchers responsible for request assignment

This work has been partially funded by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) within the strategic program FIT-IT ModSim under grant 822739 (project HealthLog).
Problem Description

- About 60% of the requests are known in advance
- The remaining requests are dynamically occurring throughout the day
- Minimizing the total travel time and waiting time
- Hard and soft time windows
- Max. 30 minutes detour
- Unpredictable situations
Overall System Design

Request Optimization
Overall System Design

Request Optimization

Real Data

Database

Request optimization

generate recommendations
for dispatcher
Overall System Design

Stochastic Modeling
Stochastic Modeling

- Demand Modeling
- Classification into postal districts
- Hourly demand for transports between all districts
Overall System Design

Stochastic Modeling

Diagram showing the flow of data and processes involving Real Data, Database, Request Thread, Stochastic Model Requests, Stochastic Model Travel Times, Distance Thread, Reference Travel Times, Expected Travel Times, and a Router.
Stochastic Modeling

- Travel Time Modeling
- Reference travel times
- Considers traffic conditions and seasonal effects
- Expected travel time
Overall System Design

Request Optimization
Overall System Design

Request Optimization

- Starting solution for static requests
- Incorporate stochastic information
- Deal with dynamic behavior
- Solution should be updated quickly in case of modifications
- Fast insertion heuristics
- Continuous background optimization
Dynamic Programming Approach for DARP

- Giant tour representation: state definition
  - \((S, j, A_j, L), \ j \in S, \ S \subseteq V \setminus o_1\)
  - \(S\) contains all request and vehicle nodes
  - The arrival time \(A_j\) at the last visited node \(j\)
  - The user ride time \(L\) for each patient aboard

- One state dominates another if:
  - it has a smaller travel distance
  - and an earlier begin of service time
  - and smaller user ride time for all patients aboard

Results for exact DP Approach

- Cordeau instances with up to 24 requests solved
- Real world instances with up to 20 requests solved
Restricted DP Approach for benchmark

- In order to deal with larger instances
  → Extend exact DP approach to a heuristic approach

- All states of a stage are sorted according to a quality metric, determining the most promising states in a stage

- Only the $B$ best states are selected and expanded

- Criterion function considers:
  - Current tour length
  - Required travel distance to serve all remaining requests using a separate vehicle
  - Average remaining time for not yet served requests
Restricted DP Approach for ASB instances

- Adapt the restricted DP for the classic DARP
- Introduce new constraints relevant for ASB instances
- Modify the Objective function
- Criterion function considers:
  - Current tour length
  - Delay of patients at pickup location
  - Waiting time of vehicles
  - Overtime of drivers
Results for the restricted DP Algorithm

- Tested on benchmark data sets introduced by Cordeau and Ropke with up to 96 requests

<table>
<thead>
<tr>
<th>Restricted DP algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Optimal solution found for eight instances (out of 24)</td>
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<tr>
<td>■ Comparison with tabu search by Cordeau/Laporte: Better solutions are found in less runtime</td>
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Restricted DP algorithm

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Results for the benchmark data set

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Real World Instances

- One day of the ASB from 06:00 to 20:00
- Served 318 transportation requests with 42 vehicles
- With a total travel time of 85.5h, total waiting time for patients of 84.4h and 9.5h overtime

Results

- Total travel time of 72.9h
- Total waiting time for patients of 1.6h and no overtime
- Less vehicles used (9 vehicles)
- Solution obtained in less than 1 minute
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Summary and Outlook

- Framework for solving dynamic and stochastic DARP
- Benchmark and large real world instances
- Stochastic models for demand and travel time
- Competitive Restricted dynamic programming approach
- VNS/LNS based on DP/RDP
- Full dynamic and stochastic approach
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