Evolutionary Freight Transportation Planning

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http://www.it-weise.de/
Contents

- The *in.west* Project
- Freight Transportation Challenge
- Optimization Problem
- Approach
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• Freight traffic is steadily increasing

• *in.west* is a research project funded by the German Federal Ministry of Economics and Technology.

• Goal: Reduce freight traffic by 10%
• Focus on container-based freight transportation

Swap Body
C 745 / EN 284
- Holistic Approach
- Sensor Nodes
- Web-based GUI
- Transportation Planner
- Middleware
Freight Transportation Challenge

- Freight transportation for real-world logistics company
- Find routes on the map and assignments of orders to containers and containers to trucks/trains which minimize the undelivered orders and the total distance for…
Freight Transportation Challenge

- Freight transportation for real-world logistics company
- Orders/Containers/Trucks/Trains/Routes for …
- Multiple depots and pickup and delivery locations

Diagram:
- MDVRP: multi-depot VRP
- VRP: periodic VRP
- PVRP: real-world problem in DHL/Inwest
- DVRP: distance or time constraints
- VRPTW: capacity constraints
- CVRP: time windows
- DCVRP: backhaul
- VRPPD: w. loading and unloading
- VRPSPD: w. depot is src and dest
- VRPB: capacity const.
Freight Transportation Challenge

- Freight transportation for real-world logistics company
- Orders/Containers/Trucks/Trains/Routes for …
- Multiple depots and pickup and delivery locations
- Vehicles (trucks and trains) have capacity limits
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Freight Transportation Challenge

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- Orders/Containers/Trucks/Trains/Routes for …
- Multiple depots and pickup and delivery locations
- Vehicles (trucks and trains) have capacity limits
- Time windows for pickup and delivery
- Constraints, laws, time limit: 1d

Diagram:
- MDVRP (multi-depot VRP)
- VRP
- PVRP
- DVRP
- CVRP
- VRPTW
- DCVRP
- VRPPD
- VRPB
- VRPSPD

Real-world problem in the DHL / in-west
Optimization Problem

- Goal of optimization is to find a freight transportation plan
- Minimize number of undelivered orders, distance, spare capacity

\[ f_1 \] Minimize no. of undelivered orders
\[ f_2 \] Minimize distance
\[ f_3 \] Minimize spare capacity

Diagram:
- Location
  - startLocationID
  - endLocationID
  - minStartTime
  - maxStartTime
  - minEndTime
  - maxEndTime

- Order
  - startLocationID
  - endLocationID
  - minStartTime
  - maxStartTime
  - minEndTime
  - maxEndTime

- Tour
  - startLocationID
  - endLocationID
  - startTime
  - endTime
  - orderIDs[]
  - swapBodyIDs[]
  - vehicleID

- Plan
  - 1..*

- SwapBody
  - *

- Vehicle
  - 1..*

- Number of undelivered orders, distance, spare capacity

\[ \cdots \]
Approach: Genotype/Phenotype

- Evolutionary Algorithm
- Transportation Plan = Phenotype = Genotype
Approach: Search Operations

- Always create valid and physically correct phenotypes
- 16 mutation operations
- 3 recombination operators
- Each operation dedicated to one specific constellation in the solution candidates
- Reproduction: randomly choose operation, if not applicable choose another one (and so on)
Approach: Search Operations

- Mutation: Add new tours for undelivered freight to plan
Approach: Search Operations

- Mutation: Integrate delivery in existing tour
Approach: Search Operations

• Mutation: Freight exchange / Truck-meets-Truck
Approach: Search Operations

- Mutation: Transport freight via trains

- For each operation, there is an inverse operation
Approach: Search Operations

- Crossover: Combine tours from parents
Experiments: Test Data

- Original data from the DHL

- 4th quarter 2007
- 800 swap bodies
- 11 depots
- 801 pickup/delivery locations
- 169...2980 orders/day
- 76% fill rate, lean flow of goods
Experiments: Find Good Settings

- Data set of 2007-12-02, 189 orders, original: 19,019 km
- Tested settings:
  - steady state / generational
  - elitism / no elitism
  - population sizes: 200, 500, 1000
  - Pareto ranking with and without sharing
  - muta. rate: 0.6/0.8 crosso. rate: 0.2/0.4
  - convergence prevention (clearing) 0.0/0.3
- 192 configurations à 10 runs
Experiments: Find Good Settings

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  - muta. rate: 0.6/0.8 crosso. rate: 0.2/0.4
  - convergence prevention (clearing) 0.0/0.3
- 192 configurations à 10 runs: 172 configs better than original
- Best configuration: 80% mutation, 40% crossover, ps = 1000, steady state, elitism, sharing, cp = 0.3
  15883 km in total or 16% saved
Experiments: Tests with various data sets

Fri, 2007-12-07
1987 orders
original: 174924 km
A assign all orders
B improve solutions
new 173916 km
Experiments: Tests with various data sets

Mon, 2007-12-24
642 orders
original: 63812 km
A assign all orders
B improve solutions
new: 54993 km
Experiments: Tests with various data sets

Sat, 2007-11-03
1016 orders
original: 82013 km
A assign all orders
B improve solutions
100%: 79463 km
99%: 74435 km
Online Re-Planning

- **A**: [10:00, 11:30]
- **B**: [08:00, 09:00]
- **C**: [11:00, 13:00]
- **D**: [15:30, 16:15]
- **E**: [14:30, 15:30]
- **F**: [17:00, 19:00]
- **G**: [11:00, 13:00]
- **H**: [11:00, 13:00]
Online Re-Planning

Diagram showing locations A, B, C, D, E, F, G, H with time markings. The diagram illustrates the online re-planning process with arrows indicating the movement of trucks between locations and time stamps at each location.
Online Re-Planning

A  13:00
D  12:00+1h
E  16:00
B  11:00+1h

C  8:30
H  7:00
G  15:00+1h
F  18:30

[x:11:30] [y:15:30] [z:19:00]
Online Re-Planning

A 11:00

B 11:00+1h

C 8:30

D 12:00

E 16:00

F [z:19:00] 18:30

G 15:00

H 7:00

[x:11:30]

[y:15:30]
Conclusions

• Planning in real-world logistics companies is hard

• Evolutionary approach with dedicated representation and search operations has been provided

• Extensive tests have been performed

• Improvement: never < 1%, normally ≈ 5%, best ≥ 15%

• Offline and online optimization

• Field test of complete in.west system this fall

• Distribution, further improvements
Thank you very much for your attention!

Any questions?

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Experiments: Find Good Settings

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