Evolutionary Freight Transportation Planning

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Contents

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- Freight Transportation Challenge
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Freight traffic is steadily increasing.

- **in.west** is a research project funded by German Fed. Minist. of Econ. a. Tech.
- Goal: Reduce freight traffic by 10%
- Focus on container-based freight transportation
• 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
Freight Transportation Challenge

- Freight transportation for real-world logistics company
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- Vehicles (trucks and trains) have capacity limits
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- Vehicles (trucks and trains) have capacity limits
- Time windows for pickup and delivery
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
- Time windows for pickup and delivery
- Constraints, laws, time limit: 1d
Optimization Problem

- Goal of optimization is to find a freight transportation plan
- Minimize no. of undelivered orders, distance, spare capacity

### Optimization Problem Diagram

- **Location**: startLocationID, endLocationID
- **Order**: startLocationID, endLocationID, minStartTime, maxStartTime, minEndTime, maxEndTime
- **Tour**: startLocationID, endLocationID, startTime, endTime, orderIDs[], swapBodyIDs[], vehicleID, 1..*
- **Plan**: 1..*
- **SwapBody**: *
- **Vehicle**: *

### Optimization Problem Equations

- $f_1$: Minimize undelivered orders
- $f_2$: Minimize distance
- $f_3$: Minimize spare capacity
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 (trucks meet)

- Mutation: Freight exchange / Truck-meets-Truck

\[ \text{Diagram showing a before and after state of trucks meeting and exchanging freight.} \]
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: 19019 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

- Data set of 2009-12-02, 189 orders, original: 19,019 km

- Tested settings

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  - 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
  15,883 km in total or 16% saved

better in two-tailed significance tests with $\alpha = 2\%$
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

Distance in km

original performance
first time a complete plan was found

Generations
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

[10:00,11:30]
[08:00,09:00]
[11:00,13:00]
[14:30,15:30]
[15:30,16:15]
[17:00,19:00]

[10:00,11:30]
Online Re-Planning

A

13:00

B

11:00

C

8:30

D

12:00

E

16:00

F

18:30

G

15:00

H

7:00

[x:11:30]

[y:15:30]

[z:19:00]
Online Re-Planning

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

B [x:11:30] 11:00+1h

C 8:30

F [z:19:00] 18:30

G 15:00+1h

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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