The Node Edge Arc Routing Problem
- applications and heuristics

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Outline

- Challenges for Routing Technology
- Heuristic Strategies for Large-Scale VRPs
- Newspaper and media product distribution
- The Node Edge Arc Routing Problem (NEARP)
- Conclusions
Messages

- Many challenges for routing technology
- Computational complexity is one of them
- Several strategies for containing complexity
- The Node Edge Arc Routing Problem (NEARP, or the Multi-vehicle Capacitated General Routing Problem on a Mixed Graph) is scientifically interesting and highly relevant to industry
Challenges for Routing Technology

- Industrial awareness
- Information accessibility
- User interfaces
- Model adequacy and flexibility
- Software engineering
- Robustness
- Solution quality for large-size and complex problems
- Computational complexity
- Newspaper distribution
- City of Oslo
- 500k inhabitants
- 200k households
- 35k modules
Applied Mathematics
How to contain complexity?

- Good algorithms
- Decomposition
- Abstraction, problem reduction
- Parallel computing
- Search reduction
Abstraction

- Ignoring detail, bottom-up
- Always done, modelling
  - Euclidean distances
  - Cost is distance
  - Constant speeds
  - Identical vehicles
  - Triangle inequality
  - Linearization
  - ....
  - May reduce industrial relevance ...
- Aggregation
Aggregation of demand

- Collection of transportation demand
- Use of road topology
- Capacity threshold
- Other constraints

- De-aggregation and further improvement
- Multi-level aggregation / refinement

- < 10 papers in the literature
Demand aggregation based on road topology, proximity

- Oppen & Løkketangen [C&OR 2006]
- Distance/time, capacity may stop aggregation
- Issues on traversal possibilities, constraints
- Typical reduction factor of 5-20
- Needs extention to arc model (Node Edge Arc Routing Problem, NEARP)
Aftenposten 33.200 orders -> 5.600 aggregates
<table>
<thead>
<tr>
<th>Bestemmelser</th>
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<tbody>
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**Kostnader:**
- 0 min
- 0 min
- 0 min
- 0 min
- 0 min

**Avstander:**
- 3,3 km
- 12,00 km
- 0,35 km
- 0,15 km
- 0,20 km
- 0,15 km
- 0,00 km

**Beregnet tid:**
- 12,00 min
- 72,10 min
- 0,00 min
- 0,00 min
- 0,00 min
- 0,00 min
- 0,00 min

**Resultater:**
- 246,13 min
- 246,13 min
- 246,13 min
- 246,13 min
- 246,13 min

**Beregning:**
- Beregnet tid: 246,13 min
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Node and Arc Routing

- For "Household routing problems" demand is really located in a node
  - mail delivery
  - newspaper and other media products
  - waste collection
  - typically modelled as CARP in the literature
- "Real" arc routing problems
  - snow removal, road cleaning, road maintenance
  - gritting, salting, ...
- Abstraction, aggregation of demand
  - mix of nodes, arcs, edges
  - travel cost (deadheading), service cost
- Node Edge Arc Routing Problem (NEARP)
  - Christian Prins and Samir Bouchenoua 2004
  - Generalization of the CVRP, CARP, General Routing Problem
  - Multi-vehicle Capacitated General Routing Problem on a Mixed Graph
  - Definition, test problems, memetic algorithm
Aftenposten 33.200 orders -> 5600 aggregates
VRP solver - Spider

- Rich model
- A single algorithmic machinery
  - construction phase
  - tour depletion phase(s)
  - iterative improvement
    - VND
    - destroy and rebuild
  - different phases, each with its own objective
- Good results on a variety of benchmarks from the literature
- More computing time than focused academic solvers
- Has been commercialized through several channels
Previous situation

- Every task (pickup, delivery, tour start/end...) has a **location**
- Topology Module (Guider) provides distance, cost and time services:
  - $d(l_1, l_2)$, $c(l_1, l_2)$, $t(l_1, l_2)$
  - Possibly time dependent
  - Not necessarily symmetric
  - Triangle inequality holds
- Special location **Anywhere**
- Tasks may have alternative locations
- One is selected in plan
Extending locations

- Previously: Only Node Locations
- New type of locations: Edge Locations
- From: Node location
- To: Node location
- Reversible: bool
Impact on topology

- $d(l_1, l_2), c(l_1, l_2), t(l_1, l_2)$

- When $l_1$ is edge, use $l_1$: To

- When $l_2$ is edge, use $l_2$: From

- Triangle inequality may not hold
Impact on operators

- When reversing subtours (2-opt, 3-opt), we reverse all reversible edge locations

- That’s it
Edge locations

- Aggregation along road segments
- Modelling Arc Routing Problems, mixed problems
- All model extensions may be used
  - Non-homogenous fleet
  - Linked tours with precedences
  - Mixture of order types: Deliveries, Pickups, Direct, Single Visits
  - Multiple time windows, soft time windows
  - Capacity in multiple dimensions, soft capacity
  - Alternative locations on tours and orders
  - Periodic orders, alternative time periods
  - Non-Euclidean, asymmetric, dynamic travel times
  - A variety of constraint types and cost components ...

- Same algorithmic machinery, no ARP operators
- Performance?
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<th>04 Askar &amp; Barum, M1-6</th>
<th>OIV gr1 Lab</th>
<th>Ant. ruter: 1</th>
<th>Lagt inn: 16:09 (28.04.2009)</th>
<th>Startet: 16:00</th>
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NEARP experiments

- Intel Core2 Duo T7800 2.6 GHz, 3.5 Gb memory, MS Windows XP Professional version 2002 SP 2
- Neighborhood operators
  - Insert
  - Relocate
  - 2-opt
  - 3-opt
  - Cross (2-opt*)
  - Cross-exchange (2 variants)
- Diversification: destroy and repair
- 900/1800 seconds timeout
Computational tests - NEARP

- Prins & Bouchenoua CBMix (23 instances)
- No lower bounds yet, no proven optima, only one competitor
- UB error 0.94%
- 8 best known solutions (6 new), 0 incomplete ...
- 519 seconds

- Improvements needed, exploit ARP-structure
Conclusions

- Many challenges for routing technology
- Computational complexity and detailed information are two
- Aggregation heuristics provide an important remedy
  - problem reduction
  - abstraction
- The NEARP is an interesting model, more work needed
- Robust algorithms for rich node-routing problems is a good starting point
- Needs algorithmic extensions that handle ARP structure
- Work has been started to provide good lower bounds for the NEARP
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Tromsø 69°40′58″N 18°56′34″E
Seventh Triennial Symposium on Transportation Analysis
Tromsø, Norway, June 20.-25., 2010
http://www.tristan7.org/
Deadline for abstract submission: October 31, 2009
The Collab project

- High-performance transportation optimization through parallel and collaborative methods
- Rich VRP, Dynamic SPP
- 2009-2011
- Partners
  - Group of optimization, SINTEF ICT
  - Group of Heterogeneous Computing, SINTEF ICT
  - The Agora Innoroad Laboratory, University of Jyväskylä, Finland
  - ITMMA, University of Antwerp, Belgium
  - CIRRELT, Quebec, Canada
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- Funded by the Research Council of Norway / SMARTRANS
- Extensions