A Savings-based Randomized Heuristic for the Heterogeneous Fleet Multitrip VRP

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Outline of the Presentation

► Introduction
  ▪ Motivation
  ▪ Problem description
  ▪ Literature review
► Savings-Based Randomized Heuristic
  ▪ The method
  ▪ Computational results
► Real application
► Conclusions and directions of future work.
Introduction - Motivation

Actual Project - Grup Alimentari Guissona

- Food Industry
- Integrated logistics network
- Redesign the Vehicle Distribution Problem
  - 370 stores in Spain
  - Revenue 1,156 million euros
  - Three types of products (dry, fresh, frozen)
  - Centralized warehouse (La Closa, Guissona, Catalonia)
  - Daily distribution (Monday to Saturday)
Introduction - Motivation

Routing Problem
- Heterogeneous fleet (7 different truck capacities)
- Time windows in the stores
- Constraints of assigning some trucks to some stores.
- Maximum driving hours
- Multitrip for some vehicles
- Etc.
- Minimize operative costs

Distribution System
- Stores place orders
- Order planning (adjust orders according inventory)
- Route planning
  * Actually is planned manually, adjusting master routes according to the demand.
  * Order planning (adjust orders according truck capacity)
- Load trucks
- Start delivery

The new algorithm should run in less than 20 minutes…
**Introduction- The Problem**

- Heterogeneous Fleet Multitrip VRP (1/2)
  - A direct graph $G = (V, A)$ is given, where $V = \{0, 1, \ldots, n\}$ is the set of $n + 1$ nodes and $A$ is the set of arcs.
  - Node 0 represents the depot, while the remaining nodes $V' = V \setminus \{0\}$ corresponds to the $n$ customers.
  - Each customer $i \in V'$ requires a supply of $q_i$ units from the depot (assume $q_0 = 0$).

- Heterogeneous Fleet Multitrip VRP (2/2)
  - The vehicle fleet is composed by $m$ different vehicle types, with $M = \{1, \ldots, m\}$.
  - For each vehicle type $k \in M$, the capacity is $Q_k$.
  - There is a limited number of vehicles of each type ($m_k$)
  - It is allowed to do multitrip.
  - Some vehicles cannot go to some customers
    - (Min dem>min cap)
  - **Minimize the total distance**
Introduction - Review

Vehicle Routing Problems

- GCVRP
- CVRP
- HCFRP
- CVRP(MT)
- CVRP(ST)
- HFMVRP
- HCVRP(ST)
- HFMVRP (A) (max dem<min cap)
- HFMVRP (B) (Min dem>min cap)
- HFFVRP (Fixed Fleet)
- HCVRP/VFMP (Unlimited)

Main References

Savings-Based Randomized Heuristic

► Our approach will be based on the Clarke and Wright’s savings (CWS) algorithm (Clarke & Wright 1964).
  - SR-GCWS-CS: SimoRouting Clarke and Wright’s Savings with Cache an Splitting


Savings-Based Randomized Heuristic

► CWS: the first edge (the one with the most savings) is the one selected.
► GCWS introduces randomness in this process by using a quasi-geometric statistical distribution
  - edges with more savings will be more likely to be selected at each step, but all edges in the list are potentially eligible.
► Cache method:
  - A hash table is used to save, for each generated route, the best-known sequence of nodes (this will be used to improve new solutions)
Savings-Based Randomized Heuristic

- Splitting (divide-and-conquer) method:
  - Given a global solution, the instance is subdivided in smaller instances and then the algorithm is applied on each of these smaller instances.

1. Select routes on the SE area (area below the diagonal)
2. Consider the new CVRP subproblem
3. Solve the subproblem and reconstruct the solution

Savings-Based Randomized Heuristic

- Assign vehicles to routes
- Procedure TryToAssign to assign trips to trucks (Prins 2002)
  - When try to join to routes
  - Build a list of pair (route, capacity, vehicle) for the remaining routes;
  - Add the join route pair
  - Sort in decreasing order of vehicle load
  - Sort the vehicles in decreasing order of capacity
  - Assign vehicles to route
  - If no feasible assignment, the routes cannot be join.
Savings-Based Randomized Heuristic

Start

- Compute initial dummy solution and list of savings’ edges
- Clarke & Wright, 1964

Sort the list of savings’ edges with a biased random criterion
- Juan et al., 2010

Extract a saving edge from the list

- 
- maxRouteLength
- Is mergedCost <= maxRouteLength?
- Yes
- Compute decreasing sorted list of vehicles and decreasing sorted list of routes’ loads
- Prins, 2002
- No

- alpha

Unify routes

- Each route load can be assigned to a candidate vehicle? (load <= vCap)
- Yes
- No

Assign final vehicles

- Apply 2-Opt-based Local Search
- Croes, 1958
- No

Is empty the savings’ edge list?

- Yes
- Apply cache-based Local Search
- Juan et al., 2011

Apply splitting-based Local Search

- maxSplitter

Update best found solution

- maxTime
- Is time <= maxTime?
- Yes
- No

End
Computational Results

► Prins’ instances

- Proposed in Prins (2002), these are twenty random instances, denoted as Prins_ {i} (i = 1, 2,..., 20).
- Each instance contains 100 customers uniformly distributed in a 200 x 200 km² grid.
- Each customer’s demand is uniformly distributed in [1, 100].
- The depot is placed at the center of the grid, and the maximum time allowed per route is 300 minutes (or 350 km at a speed of 70 km/h).
- The fleet is composed by \( k = 9 \) types of vehicles with \( m_k = 2 \) for all \( k = 1, 2,..., 9 \).
- Each type of vehicle has a capacity given by \( Q_k = 600 - 50(k - 1) \).

Golden et al. (1984)

- proposed 20 instances for the Fleet Size and Mix vehicle Routing Problem of different sizes
- Taillard (1999) defined the number of available vehicles of each type.
- the number of customers is in the range of 50 and 100.

<table>
<thead>
<tr>
<th>Instance</th>
<th>( Q_A )</th>
<th>( m_A )</th>
<th>( Q_B )</th>
<th>( m_B )</th>
<th>( Q_C )</th>
<th>( m_C )</th>
<th>( Q_D )</th>
<th>( m_D )</th>
<th>( Q_E )</th>
<th>( m_E )</th>
<th>( Q_F )</th>
<th>( m_F )</th>
<th>( % )</th>
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<td>30</td>
<td>2</td>
<td>40</td>
<td>4</td>
<td>70</td>
<td>4</td>
<td>120</td>
<td>2</td>
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<td>1</td>
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<td>4</td>
<td>200</td>
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<td>4</td>
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<td>250</td>
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<td>400</td>
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<td>3</td>
<td>300</td>
<td>3</td>
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<td></td>
<td></td>
<td></td>
<td>95.92</td>
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</tbody>
</table>
Computational Results

- Li et al. (2007): five large-scale HVRP instances, inspired by Golden et al., and denoted as Li\_i, with i = 1, ..., 5. Number of customers is between 200 and 360, and each case has a geometric symmetry with nodes located in concentric circles around the depot.

<table>
<thead>
<tr>
<th>Instance</th>
<th>Q_a</th>
<th>m_a</th>
<th>Q_b</th>
<th>m_b</th>
<th>Q_c</th>
<th>m_c</th>
<th>Q_d</th>
<th>m_d</th>
<th>Q_e</th>
<th>m_e</th>
<th>Q_f</th>
<th>m_f</th>
<th>%</th>
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<td>8</td>
<td>100</td>
<td>6</td>
<td>200</td>
<td>4</td>
<td>500</td>
<td>3</td>
<td>1000</td>
<td>1</td>
<td>93.02</td>
<td></td>
<td></td>
</tr>
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<td>H2</td>
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<td>10</td>
<td>100</td>
<td>5</td>
<td>200</td>
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<td>500</td>
<td>4</td>
<td>1000</td>
<td>1</td>
<td>96.00</td>
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<td>5</td>
<td>200</td>
<td>5</td>
<td>500</td>
<td>4</td>
<td>1000</td>
<td>2</td>
<td>94.76</td>
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<td>1000</td>
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<td>1500</td>
<td>1</td>
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<td>8</td>
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<td>1000</td>
<td>2</td>
<td>1500</td>
<td>1</td>
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Computational Results

- Summary

<table>
<thead>
<tr>
<th>Instance</th>
<th>Customer</th>
<th>Demand</th>
<th>Total Cost</th>
<th>Time</th>
<th>Gap</th>
<th>Average Cost</th>
<th>Gap</th>
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<td>CWS-Prins</td>
<td></td>
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<td>2692.57</td>
<td>10.9</td>
<td>0.08</td>
<td>2562.97</td>
<td>-4.78%</td>
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<td>Randomized CWS-Prins</td>
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<td>2584.6</td>
<td>10.65</td>
<td>24.5</td>
<td>749.33</td>
<td>-5.34%</td>
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</table>

<table>
<thead>
<tr>
<th>Instance</th>
<th>Customer</th>
<th>Demand</th>
<th>Total Cost</th>
<th>Time</th>
<th>Gap</th>
<th>Average Cost</th>
<th>Gap</th>
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<tbody>
<tr>
<td>GT</td>
<td>50-100</td>
<td>Average</td>
<td>767.73</td>
<td>9.17</td>
<td>0.05</td>
<td>741.9</td>
<td>-6.12%</td>
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<td>H</td>
<td>200-360</td>
<td>Average</td>
<td>9765.44</td>
<td>20.6</td>
<td>58.61</td>
<td>9431.48</td>
<td>-3.31%</td>
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</table>
Real Application

► Grup Alimentari Guissona RESULTS

- Fleet Composition of the Distribution Company

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Q₀</th>
<th>m₀</th>
<th>MQ₀</th>
<th>AM₀</th>
<th>MQM₀</th>
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<tr>
<td>A</td>
<td>222</td>
<td>8</td>
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<td>B</td>
<td>414</td>
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<tr>
<td>C</td>
<td>482</td>
<td>139</td>
<td>66.998</td>
<td>2</td>
<td>133.996</td>
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<tr>
<td>D</td>
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<td>1.650</td>
<td>1</td>
<td>1.650</td>
</tr>
<tr>
<td>E</td>
<td>616</td>
<td>6</td>
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<td>1</td>
<td>3.696</td>
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<tr>
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<td>676</td>
<td>3</td>
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<td>2.028</td>
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<td>1.210</td>
<td>1</td>
<td>1.210</td>
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<td>TOTAL</td>
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<td>75.691</td>
<td>149.434</td>
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**Company Solution**

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<th>Instance</th>
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<th>Time</th>
<th>Gap</th>
<th>Cost</th>
<th>Time</th>
<th>Gap</th>
<th>Average</th>
<th>Gap</th>
<th>Gap</th>
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<td>A</td>
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<td>39534.11</td>
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<td>-11.70%</td>
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<tr>
<td>B</td>
<td>47184.35</td>
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<td>-11.37%</td>
<td>41072.46</td>
<td>55.2</td>
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<tr>
<td>C</td>
<td>53941.43</td>
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<td>48669.31</td>
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<tr>
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<td>-8.88%</td>
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<td>42999.49</td>
<td>46.46</td>
<td>-11.88%</td>
<td>1.57%</td>
<td>-0.80%</td>
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</table>
Real Application

► Grup Alimentari Guissona RESULTS
  - Savings 10% daily with respect to the actual solutions.
  - Savings of 2% compared with Prins Algorithm.
  - The average number of routes were similar, with a small reduction for our solutions.

Conclusions

► After 50 years research, VRP is still a relevant and interesting problem…
► Research should focus on solving real problems, they are more difficult than the classic well-known VRP.
► Heuristics and Metaheuristics are an excellent tool to solve real VRP.
► Companies require no fine-tunning or parameters to be set.
Future Research

- Heterogeneous Fleet Multitrip VRP
  - Improve the algorithm, in particular the truck assignment
  - Include time windows
- Blood sample collection VRP
  - Interesting and relevant applications in Health Sector
- More VRP real applications (fashion industry)
  - MANGO
  - DESIGUAL
- vrp.upf.edu (VRP in Google maps)