A decision support system for vehicle routing based on model inversion and data analysis

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Agressive competition $\rightarrow$ reactivity to customer demands (costs minimization, quality of service)

Vehicle Routing Problems (VRPs) optimization

VRP: Determine the routes to be performed by a fleet of vehicles to serve a given set of customers
Problem statement

- Take into account the real-world routing environment constraints: capacity, time windows, ...

OR: methods to efficiently solve the variants of VRPs [Toth and Vigo, 2002]

Important limitations:
- human factors are not much considered in the modelling and in the solving phase of the problem
- models and solving systems are not ready to deal with the rapid changing situations
- lack of a decision support tool when the problem is not satisfiable

We propose an interdisciplinary approach for the DSS [Gacias et al., 2009]
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Decision Support System (DSS)

- Two different components:
  - Solving Mechanism based on Operational Research techniques
  - Human Interface based on Work Domain Analysis and where the human aspects are considered

- 3 independent phases:
  - Vehicle selection
  - Customer allocation
  - Route creation
Solving mechanism

- VRP algorithms for customer allocation and route creation
- 3 control modes → Automatisation
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Model Inversion

What we can do when the problem is not satisfiable?
- Model inversion to offer user support for constraint relaxation

What the model inversion is?
- decision variables $\rightarrow$ parameters
- parameters $\rightarrow$ decision variables

We propose model inversion techniques for the vehicle selection phase
Model inversion for the vehicle selection phase

- Decision: Vehicles to use to solve the problem
- Capacity constraints satisfaction (weight, volume, length)
- Compute a lower bound for the number of vehicles
Model inversion for the vehicle selection phase

Methodology

- Identify the parameters of the constraints
- Each constraint has its own model inversion mechanism
  - Identify the parameters susceptible to be modified
  - Data analysis to select the parameters to modify
    - Geographic criterion
    - Temporal criterion
Model inversion for the vehicle selection phase

Geographic criterion

- \( k \)-means algorithm to compose \( m \) groups of customers

Iteration 1

\( c_1 \) \( g_1^1 \) \( g_1^2 \)

\( c_2 \)

Iteration 2

\( g_1^1 \) \( g_1^2 \)

\( g_2^1 \) \( g_2^2 \)
The customers being part of the same cluster have a high probability to belong to the same route.

For each customer \( i \) of cluster \( P_k \) the mean distance between the customer with the other customers of the cluster is computed

\[
dm_i = \frac{\sum d_{ij}}{|P_k| - 1}, \quad j \in P_k
\]

The \( dm_i \) is used as indicator to decide whether a customer is candidate to be suppressed.
Temporal criterion

- We propose a dissimilarity index to measure the degree of centering between two time windows

\[
\delta(i, j) = \begin{cases} 
1 - \frac{\min(d_j - r_i, d_i - r_j)}{\max(d_j - r_i, d_i - r_j)} & \text{if } \min(d_i, d_j) \geq \max(r_i, r_j), \\
1 - \frac{\min(d_j - r_i, d_i - r_j)}{\frac{1}{n} \sum_{i=1}^{n} (d_i - r_i)} & \text{otherwise}. 
\end{cases}
\]
Dynamic cluster algorithm to group the customers with overlapping TW

Identify the set(s) of critical customers (criterion $|P_k| > \text{limit}$)

k-means algorithm (only for the critical customers) to identify the customers to suppress in priority

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Gacias, Cegarra, Lopez (LAAS, CLLE)  A decision support system for vehicle routing甲
Example

- Problem with 7 customers $C_i$ with TW $[r_i, d_i]$
- $Bl_{nv} = 3$ because of TW
  - $V(C_3) \neq V(C_4)$
  - $V(C_3) \neq V(C_6)$
  - $V(C_4) \neq V(C_6)$
- The planner proposes a solution with only two vehicles $\rightarrow$ not satisfiable
Model inversion for the vehicle selection phase

Exemple

- Identification of the parameters: decision to serve the customers $C_3$, $C_4$ and $C_6$
- Geographic criterion (k-means algorithm) $\rightarrow C_6$
- Temporal criterion (dynamic cluster algorithm + k-means algorithm) $\rightarrow C_4$
- The planner decides which customer is suppressed
Model inversion for the vehicle selection phase

Exemple

- Identification of the parameters: decision to serve the customers $C_3$, $C_4$ and $C_6$
- Geographic criterion (k-means algorithm) $\rightarrow C_6$
- Temporal criterion (dynamic cluster algorithm + k-means algorithm) $\rightarrow C_4$
- The planner decides which customer is suppressed

\[ C_2 \times \times \times C_4 \]

[Depot]

\[ \times \]

\[ C_6 \]
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### Computational Results

56 instances

<table>
<thead>
<tr>
<th>nc = 9</th>
<th>Nb_Opt_Dist</th>
<th>Avg_Opt</th>
<th>Avg_Pos</th>
<th>Nb_Sol</th>
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</thead>
<tbody>
<tr>
<td><strong>GC-C</strong></td>
<td>13 (17)</td>
<td>8.73 %</td>
<td>2.7</td>
<td>6</td>
</tr>
<tr>
<td><strong>GC-R</strong></td>
<td>9 (23)</td>
<td>5.99 %</td>
<td>3.5</td>
<td>17</td>
</tr>
<tr>
<td><strong>GC-RC</strong></td>
<td>9 (16)</td>
<td>5.01 %</td>
<td>3.2</td>
<td>5</td>
</tr>
<tr>
<td><strong>TC-C</strong></td>
<td>5 (17)</td>
<td>14.98 %</td>
<td>4.5</td>
<td>7</td>
</tr>
<tr>
<td><strong>TC-R</strong></td>
<td>3 (23)</td>
<td>11.46 %</td>
<td>5.4</td>
<td>7</td>
</tr>
<tr>
<td><strong>TC-RC</strong></td>
<td>4 (16)</td>
<td>9.30 %</td>
<td>5.3</td>
<td>7</td>
</tr>
<tr>
<td><strong>DDC-C</strong></td>
<td>8 (17)</td>
<td>15.76 %</td>
<td>4.3</td>
<td>8</td>
</tr>
<tr>
<td><strong>DDC-R</strong></td>
<td>5 (23)</td>
<td>10.97 %</td>
<td>4.7</td>
<td>11</td>
</tr>
<tr>
<td><strong>DDC-RC</strong></td>
<td>3 (16)</td>
<td>9.12 %</td>
<td>4.5</td>
<td>4</td>
</tr>
</tbody>
</table>

**Total** | 37 | 38
Introduction

Proposed DSS

Model Inversion

Computational Results

Conclusions and further work
Conclusions

- Interdisciplinary approach: Human factors and Operations Research techniques are considered for the DSS design
- The user participates in the solving phase
- Data analysis techniques for the model inversion when the problem becomes not satisfiable
Further work

- Propose a model inversion mechanism for each type of constraint
- Propose an algorithm for the time window relaxation
- Extend the model inversion to the other phases of the system