Applications of Intelligent Systems in Transportation Logistics

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Computational Intelligence in der Transportlogistik

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Outline

1. Introduction
2. Traffic Management
3. Fleet Management
4. Container Terminals
5. Conclusions
1. **Application of one Theory to another**
   (Fuzzy Linear Programming, Fuzzy Clustering, Fuzzy MCDM, etc.)

2. **Application of a (hybrid) Theory to a Model**
   (Fuzzy Inventory Control, Fuzzy Transportation Models, etc.)

3. **Application of Theories, Models or Methods to real Problems**
1. Introduction

Approaches in Computational Intelligence i.e. Fuzzy Sets, Neural Nets, Evolutionary Algorithms and similar methods (such as Rough Sets, Swarm Theory etc.) have a number of features that make them well suited to solve problems in logistics:

- **Uncertainty Modelling:**
  Whenever uncertainty is not due to random, but rather to *linguistic* or *possibilistic uncertainty* or to an *abundance of information*, probabilistic models are less suitable than CI - models. The same is true, when models have to be microscopic rather than macroscopic.

- **Relaxation:**
  Often models are „crisp“ or dichotomous but problems are not! (Linear Programming, Cluster Analysis!)
1. Introduction

- **Compactification** (reduction of complexity):
  The transfer from a "lack of information" to an "abundance of data" has occurred over the last three decades! Neural Nets as well as Fuzzy Sets help to discover information in data or to reduce complexity of decisions via linguistic variables, pattern recognition etc.

- **Meaning Preserving Reasoning:**
  *Expert Systems* disappointed expectations of the 70’s partly because they process symbols rather than knowledge. Their combination with Fuzzy Sets can lead to very useful decision support systems.

- **Optimization:**
  Evolutionary Computing and Generic Algorithms are known tools for optimization. Recently swarm approaches have, however, been shown effective to control uncertainty decentrally, for instance, for the control of large truck fleets.
Outline

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3. Fleet Management

4. Container Terminals

5. Conclusions
2. Traffic Management

Traffic Management (macroscopic)

Traffic Supervision:
On the basis of observations (i.e. number of cars, etc.) in some road sections and possibly other data predictions of traffic in other (critical) road sections are supplied.
2. Traffic Management

Traffic Flows at Frankfurt International Motor Show „IAA“

Travel time between 6:30 and 12:30 on work days
2. Traffic Management

- **Route Choice Models**
  Optimization and routing models are used to determine favorable routes for drivers.
  Navigation systems.
2. Traffic Management

Traffic Net Prediction
Alternating Routing

Procedure:
- Design Scenarios
- Determine traffic flows via intelligent data analysis
- Predict traffic flows
- Guide traffic such as costs or queues are minimized
2. Traffic Management

- **Traffic Control**
  Most frequently used are fuzzy models for
  - Intersection Control
  - Ramp-Metering Control
  - Detour Control
  - Coordinated Control of Traffic Networks

- **Individual Traffic Behaviour**
  Models of individual traffic behaviour are combined and used as basis for other traffic control systems.
1. Introduction

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4. Container Terminals

5. Conclusions
3. Fleet Management

Container Circulation

Empty and full, simple and refrigerated containers circulate on container ships worldwide. Empty containers accumulate where they are not needed.

**Goal:** Assign containers to ships such that transportation cost and inventories are minimized.
3. Fleet Management

Container Circulation and Storage

Problem: Determine number of empty and full (simple and refrigerated) containers (of different sizes) that shall be loaded onto a specific container ship travelling between specific harbours at a specific time.

Maximize profit and take into consideration:
- dynamic demand for containers in all harbours
- dynamically changing inventory of containers in harbours
- capacities of ships
- travel schedule

For 10 routes, 20 periods and 10 types of containers the mixed integer LP-Model contains appr. 21 000 variables and 15 000 constraints and upper bounds.
3. Fleet Management

Container Circulation and Storage (2)

By heuristic considerations this can be reduced to appr. 1 500 variables, 1 200 constraints, 1 700 upper and lower bounds (solution time on mainframe appr. 9.5 CPU -seconds).

But:
Solutions turned out to be infeasible because:
- ship capacities were considered crisp
- travel times were uncertain
- demand could only be predicted roughly
3. Fleet Management

Hence: Use of **Fuzzy Linear Programming**

Max Z = Cx

such that  \( Ax \leq b_1 \)  \( (1) \)

\[ Bx \leq b_2 \]

\[ x \geq 0 \]

The fuzzy constraints were considered as fuzzy relations with membership functions

\[ \mu_i(t_i) = \frac{t_i}{P_i - b_{1i}} \]

where \( t_i \) = tolerance variables

\( P_i \) = tolerance intervals

In this case \( \mu_i \) were integrated via penalties into objective function which lead to good results without increasing computation time.
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4. Container Terminals

Container Terminal Altenwerder, Hamburg

- **Area**: 850,000 qm
- **Quay Length**: 1,400 m
- **Quay Cranes**: 14 Super-Post-Panamax, + 2 Feeder
- **Waterside**: 53 AGVs
- **Storage:**
  - **Blocks**: 22
  - **Capacity**: 30,000 TEU
  - **Cranes**: 44 (2 / block)
- **Rail Terminal**: 6 tracks
- **Rail Cranes**: 3
- **Land Side**: 12 tractors, Transport 200 dollies
- **Road Gate**: 16 tracks, 2,500 trucks/day

**Total Capacity**: 1.9 Mio TEU/a
4. Container Terminals

Container Terminal Burchardkai (CTB), Hamburg:

From 1968 to 2014
## 4. Container Terminals | Parameters

### Landside
- **6** Rails (Train length up to 2,000 ft./ 700m)
- **4** RMG’s (Rail Mounted Gantry Cranes)
- **200** Chassis
- **20** Tractors

### Storage Area
- **22** Blocks (each 10 Lanes/ 37 Bays/ 4 – 5 Tier)
  - -> 370 Groundslots per Block
- **2** Blocks for Out of Gauge Containers (OOG I/II)
- **1** Block for empty Containers (HCCR)
  - -> 30,000 TEU's total (utilization: 80 – 90 % to improve shifting quality
- **44** RMG's (1 pair per Block)

### Waterside
- **60** AGV’s (Automatic Guided Vehicles – 15 mph/ 21 km/h
- **14** CB's (Container Bridges)
- **4** Landing Stations for GCS's (Quaylength 4,000 ft./ 1,400 m)
4. Container Terminals I
Transshipment Process

from Waterside to Hinterland
4. Container Terminals | Block Definition
4. Container Terminals | Stacking Overview

► **Optimized stacking**
  - Optimal space utilization
  - Short distances for storage and retrieval
  - Minimized rehandling

► **When?**
  - Container enters the terminal
    - CTB: 5 Mio TEU/year, 8000 boxes/day at roughly 40,000 positions
  - Storage reoptimization
    - Upon data updates
    - Remarshalling during off-peak periods
  - Rehandling

► **How?**
  - Scattered stacking
    - Terminal wide or within target areas
  - Target area filters/rules can be manually defined
4. Container Terminals | Time Constraints

**Number of inquiries**
- 14 Container Bridges (~45 – 75 sec. cycle time)
- 12 In Gates (~180 – 240 sec. cycle time)
- 4 Rail Cranes
- 30 possible questions within the 45 sec. cycle

-> Answer within ~ 1 sec. Per inquiry needed (the shorter, the better)

![Diagram of container transfer process](image)
Goal Hierarchy for Scattered Stacking in a Straddle Carrier Yard

- **SC Stack Fitness**
  - Stack
    - Distance
      - Retrieval
        - Transport?
          - Storage
          - Reshuffle
    - Tier?
      - Stack&Row Structure
        - Transport mode
      - Row structure
        - Reshuffling possibilities
          - Utilization from outside/center
          - Tier 3 utilization
          - Use of tier 3 center
          - Use of gaps in tier 3
    - New stack/new row
      - Attribute set conservation
        - Attribute set size
          - Availability
            - Attribute set
              - Weight/range
                - Half rows
            - ETS
              - Attribute set & weight
      - Existing stack
        - Rehandling probability
      - Stack?
        - Retrieval time (ETS)
          - Closed stack
4. Container Terminals | Criteria (Objectives)

a) Minimize “shifting operations“

b) Optimize utilization of storage space

c) Minimize distances from departure location
Near vs Far Inference

**Rule Block Name**

- Conclusion Variable(s)
- Method of Near Inference
- Method of Aggregation
- Condition Variables

**Rule Block Name**

- slack_time
- operation_time
- profitability
- suitability
- MIN / PROD
Project = Total Inference
### PRESELECTION (LOCATION)

<table>
<thead>
<tr>
<th>Rule</th>
<th>Condition</th>
<th>Then</th>
<th>Slot Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>destination = WS</td>
<td></td>
<td>slot_location = WS</td>
</tr>
<tr>
<td>2</td>
<td>destination = LS</td>
<td></td>
<td>slot_location = LS</td>
</tr>
<tr>
<td>3</td>
<td>destination = ? AND origin = WS</td>
<td></td>
<td>slot_location = middle</td>
</tr>
<tr>
<td>4</td>
<td>destination = ? AND origin = LS</td>
<td></td>
<td>slot_location = WS</td>
</tr>
<tr>
<td>5</td>
<td>destination = ? AND origin = ?</td>
<td></td>
<td>slot_location = middle</td>
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</tbody>
</table>

### SLOT QUALITY

<table>
<thead>
<tr>
<th>Rule</th>
<th>Condition</th>
<th>Then</th>
<th>Slot Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>departure_time = sooner</td>
<td></td>
<td>slot_quality = OK</td>
</tr>
<tr>
<td>7</td>
<td>departure_time = later</td>
<td></td>
<td>slot_quality = very_bad</td>
</tr>
<tr>
<td>8</td>
<td>carrier_Nr = same</td>
<td></td>
<td>slot_quality = very_good</td>
</tr>
<tr>
<td>9</td>
<td>carrier_Nr = different</td>
<td></td>
<td>slot_quality = bad</td>
</tr>
<tr>
<td>10</td>
<td>weightclass = lighter</td>
<td></td>
<td>slot_quality = OK</td>
</tr>
<tr>
<td>11</td>
<td>weightclass = same</td>
<td></td>
<td>slot_quality = very_good</td>
</tr>
<tr>
<td>12</td>
<td>weightclass = heavier</td>
<td></td>
<td>slot_quality = impossible</td>
</tr>
<tr>
<td>13</td>
<td>shifting = not_necessary</td>
<td></td>
<td>slot_quality = very_good</td>
</tr>
<tr>
<td>14</td>
<td>shifting = necessary</td>
<td></td>
<td>slot_quality = very_bad</td>
</tr>
<tr>
<td>15</td>
<td>GSL (groundslot) = empty</td>
<td></td>
<td>slot_quality = very_good</td>
</tr>
</tbody>
</table>
4. Container Terminals I

*fuzzy*TECH - Slot Quality
4. Container Terminals | Why fuzzyTool?

- Easier to handle
- Easier to understand
- Very easy adjustments; point & click
- Better adaptable to different applications (geography + industry); rapid application development
- Taking into consideration
  - all inputs
  - all parameters
  - uncertainty of inputs
- Very quick decision process
- fuzzyTECH is a standard system
- fuzzyTECH has open software interfaces
- Easier to integrate
4. Container Terminals | Stacking Simulation
4. Container Terminals I Stacking Simulation

Results for 3-high SC Yard

<table>
<thead>
<tr>
<th></th>
<th>Customer's actual data 15.08.07 - 12.09.07</th>
<th>Statistical model, segregation strategy</th>
<th>TerminalStar simulation</th>
<th>Statistical model, segregation strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross storage utilisation</td>
<td>53%</td>
<td>53%</td>
<td>72%</td>
<td>72%</td>
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<tr>
<td>Rehandling rate</td>
<td>0.47</td>
<td>0.55</td>
<td>0.46</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Storage utilization and rehandling rate SC-yard

4. Container Terminals | Crane Control

- CTB RMG Yard: 3 Cranes per Block
4. Container Terminals | RMG Optimization
(Simulation)
4. Container Terminals | Train Loading
4. Container Terminals | Train Loading

► Example Load Schemes

Configuration determines corner casting positions
4. Container Terminals | Train Loading

- Example Load Schemes
4. Container Terminals | Trainloading

\[
\text{max} \quad \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{s \in S_{\text{typ}(j)}} x_{ijs} \cdot (w_1 + w_2 \cdot l_i + w_3 \cdot g_i) \quad (1)
\]

\[-w_4(m - \sum_{j=1}^{m} \sum_{k \in K_{\text{typ}(j)}} \kappa_{jk}^0 \sum_{b \in B_k} y_{jb}) \quad (2)\]

\[-w_5 \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{s \in S_{\text{typ}(j)}} x_{ijs} \cdot d_{ij} \quad (3)\]

**Decision variables**
- \(x_{ijs}\) indicates that unit \(i\) assigned to position \(j\) on railcar \(s\)
- \(y_{jb}\) indicates that railcar \(j\) is configured in loading scheme \(b\)

**Objectives**
- Max utilization (1)
- Min setup costs (2)
- Min transport costs (3)
4. Container Terminals I Trainloading

\[
\sum_{j=1}^{m} \sum_{s \in S_{typ(j)}} x_{ij}s \leq 1 \quad \forall i \quad (4)
\]

\[
\sum_{k \in K_{typ(j)}} \sum_{b \in B_k} y_{jb} - 1 \quad \forall j \quad (5)
\]

\[
\sum_{i \in N_i} x_{ij}s - \sum_{k \in K_{typ(j)}} \sum_{b \in B_k} \alpha_{bks} \cdot y_{jb} \leq 0 \quad \forall j; s; t \quad (6)
\]

\[
\sum_{i=1}^{n} g_i \cdot x_{ij}s - \sum_{k \in K_{typ(j)}} \sum_{b \in B_k} \gamma_{bs} \cdot y_{jb} \leq 0 \quad \forall j; s \quad (7)
\]

- Use load unit at most once (4)
- Feasible loading scheme (5)
- Load unit fits loading position (6)
- Weight restrictions per position (7)
4. Container Terminals | Trainloading

\[
\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{s \in S_{typ}(j)} x_{ij}s \cdot g_i \leq G \tag{8}
\]

\[
\sum_{i=1}^{n} u_i^+ \cdot x_{ij}s - \sum_{k \in K_{typ}(j)} \sum_{b \in E_k} \beta_{ks}^+ \cdot y_{jb} \leq 0 \quad \forall j; s \tag{9}
\]

\[
\sum_{i=1}^{n} u_i^- \cdot x_{ij}s - \sum_{k \in K_{typ}(j)} \sum_{b \in E_k} \beta_{ks}^- \cdot y_{jb} \leq 0 \quad \forall j; s \tag{10}
\]

- Limited total weight per train (8)
- Admissible over/under-length (9 + 10)
## Dimensions and Comparison of Solution Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>average value</th>
<th>runtime</th>
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<td>relative error [%]</td>
<td>[sec]</td>
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<td>LP</td>
<td>0,80</td>
<td>810,9</td>
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<td>LP with SOS</td>
<td>0,56</td>
<td>659,3</td>
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<tr>
<td>Tabu Search</td>
<td>4,22</td>
<td>40,2</td>
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<td>Tabu Search with diversification</td>
<td>1,87</td>
<td>438,4</td>
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<td>Lengths in first instance</td>
<td>1,46</td>
<td>151,4</td>
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<td>Decomposition-Configuration</td>
<td>0,73</td>
<td>190,2</td>
</tr>
</tbody>
</table>

### Dimensions

- 30 railcars/train
- 50 – 80 load units of 5 different types
- up to 30 different configurations per railcar
- approx. 12 loading schemes per configuration
1. Introduction

2. Traffic Management

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5. Conclusions

Observations

Transportation Logistics is uncertain from several directions:
For instance in Container Harbour Control: Arrivals on Land- and Waterside, composition and locations of stored containers, resulting load requirements to different transportation equipment.

Problem is very complex due to large number of relevant relations.
Situation (context) is quickly changing (extreme dynamics).

Conclusions:

1. **Partitioning** is necessary (complexity)
2. Combination of powerful crisp methods with knowledge based technology is needed (dynamics)
3. **Approximate Reasoning** is adequate (uncertainty of different kinds, microscopic requirements)
<table>
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<th>Date</th>
<th>Who</th>
<th>Changes, Comments</th>
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<tbody>
<tr>
<td>20.08.2009</td>
<td>Andreas Becker</td>
<td>Anlegen der Datei, Master INFORM aktuell*</td>
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Anhang | Farbsystem

<table>
<thead>
<tr>
<th>Farbe 1</th>
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<th>Farbe 3</th>
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<tbody>
<tr>
<td>R255</td>
<td>R60</td>
<td>R194</td>
</tr>
<tr>
<td>G153</td>
<td>G150</td>
<td>G200</td>
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<tr>
<td>B30</td>
<td>B210</td>
<td>B200</td>
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<td>R170</td>
<td>R194</td>
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ISKE 2009
Anhang  I Textformate (Standard)

Text
- Text
- Text
4. Container Terminals | Stacking Simulation
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