Proactive Event Processing in Action: A Case Study on the Proactive Management of Transport processes

Zohar Feldman¹, Fabiana Fournier¹, Rod Franklin², Andreas Metzger³

¹ IBM Haifa Research Lab, Israel
² KLU (Kuehne Logistics University), Germany
³ Paluno Institute, University of Duisburg-Essen, Germany
Outline

- Air Freight Transportation
  - Hi-Show \ Lo-Show
- Proactive event processing solution
- Experimental study
- Summary
Air Freight Transportation

- **Air freight** constitutes a **primary channel** for shipping goods
  - Perishable
  - Expensive
  - Used in just-in-time supply network

- **Volume** (in **revenue ton-kilometers**)
  - In 2011 ~200 billion
  - By 2030 → 550 billion
Motivation

Improved management of transport processes can yield

- **Economic Impact**
  - Expected *savings of 10%-15%*

- **Ecological Impact**
  - ~25% of CO₂ emission is accountable to transport activities
  - Expected to *double by 2050*
The Case Study: **Hi Shows \ Lo Shows**

- **Exact weight cannot be determined by shippers**
  - May only be observed upon acceptance at airline

- **Discrepancies can be found in ~50% of shipments**
  - Typically lower than planned
The Case Study: **Hi Shows \ Lo Shows**

- **Exact weight cannot be determined by shippers**
  - May only be observed upon acceptance at airline

- **Discrepancies can be found in ~50% of shipments**
  - Typically lower than planned

- **Significant Implications**
  - Require re-planning the loads
    - Entails **Additional cost**
  - Shipment **delays**
  - Financial **penalties** for shippers
IATA Cargo 2000 (C2K) Monitoring Standard

- End-to-end visibility of the supply chain
- Every shipment gets a plan (aka RouteMap) with predefined milestones
- Stakeholders receive events on
  - RouteMap updates
  - Milestone completion
  - Milestone violation

FWB: Master Airway Bill Creation
DOC: Truck Arrival at Departure Airline
RCS: Freight Checked in at Airline
DEP: Goods Confirmed on Board
ARR: Flight Arrival at Destination
RCF: Freight Acceptance Arrival Airline
NFD: All Freight and Documents Ready for Pick-up
AWD: Documents Delivery to Import Forwarder
DLV: Freight Delivery to Import Forwarder
IATA Cargo 2000 (C2K) Monitoring Standard

- End-to-end visibility of the supply chain
- Every shipment gets a plan (aka *RouteMap*) with predefined milestones
- Stakeholders receive events on
  - RouteMap updates
  - Milestone completion
  - Milestone violation

Why wait for violations?
Proactive Event Processing
Prevention is more effective than cure!

- **The principal**: React to signs of a problem, *before it occurs*
Proactive Event Processing
Prevention is more effective than cure!

- **The principal**: React to signs of a problem, **before it occurs**

- **Approaches**
  - **Uncertainty Handling + Probabilistic Rules**
  - Basic proactive model
  - AI methods

Proactive Discrepancy Management Solution

- **Predict:**

  \[ p^{Hi} := P \left\{ \sum_{r \in R_f} W^A_r > \sum_{r \in R_f} W^P_r + \tau \right\} \left\{ \{ W^A_r \}_{r \in R_f^A}, \{ W^P_r \}_{r \in R_f} \right\}, I \]

  \( W^A_r \) - Actual weight of RouteMap \( r \)

  \( W^P_r \) - Planned weight of RouteMap \( r \)

  \( R_f \) - Route maps scheduled on flight \( f \)

  \( R_f^A \) - Accepted Route maps scheduled on flight \( f \)

- **Alert:**

  \[ \text{IF } p^* > \delta^* \text{ THEN alert about } "*-load" \]

  \( * = \text{Over}\ \text{or}\ \text{Under} \)
Industry Data Set

- Collected by a large freight forwarder
  - 5 months of operational data
  - Over 2 million C2K events
  - ~151,000 actual RouteMaps (transports)

<table>
<thead>
<tr>
<th>EFFECTIVE_TIMESTAMP</th>
<th>TRANSPORT_TIMESTAMP</th>
<th>DWH_TIMESTAMP</th>
<th>FLIGHT_NO</th>
<th>WEIGHT</th>
<th>PACKAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 15:10:00</td>
<td>20.09.2011 16:10:00</td>
<td>20.09.2011 16:24:42</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2011 01:55:00</td>
<td>21.09.2011 02:20:00</td>
<td>21.09.2011 02:29:16</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2011 20:03:00</td>
<td>23.09.2011 01:15:00</td>
<td>23.09.2011 01:25:16</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2011 18:45:00</td>
<td>21.10.2011 23:55:00</td>
<td>22.10.2011 00:03:53</td>
<td>492</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>2011 20:30:00</td>
<td>22.10.2011 02:50:00</td>
<td>22.10.2011 03:00:34</td>
<td>AA 8404</td>
<td>492</td>
<td>32</td>
</tr>
<tr>
<td>2011 09:00:00</td>
<td>22.10.2011 15:05:00</td>
<td>22.10.2011 15:14:53</td>
<td>AA 8404</td>
<td>492</td>
<td>32</td>
</tr>
<tr>
<td>2011 09:57:00</td>
<td>24.10.2011 09:01:00</td>
<td>24.10.2011 09:09:45</td>
<td>AA 0048</td>
<td>492</td>
<td>32</td>
</tr>
<tr>
<td>2011 10:19:00</td>
<td>24.10.2011 09:20:00</td>
<td>24.10.2011 09:26:10</td>
<td>AA 0048</td>
<td>492</td>
<td>32</td>
</tr>
<tr>
<td>2011 10:47:00</td>
<td>25.10.2011 09:50:00</td>
<td>25.10.2011 10:00:20</td>
<td>AA 0048</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>2011 12:33:00</td>
<td>25.10.2011 11:35:00</td>
<td>25.10.2011 11:39:41</td>
<td>AA 0048</td>
<td>0</td>
<td>32</td>
</tr>
</tbody>
</table>
Predicting Shipment Weight

- **Finding #1**: $W_r^A \perp I \mid W_r^P$  
  (conditional independency in other information)
Predicting Shipment Weight

- **Finding #1**: \( W_r^A \perp I \mid W_r^P \) (conditional independency in other information)
- **Assumption**: \( W_r^A \perp W_s^A \) (independency between different shipments)
Predicting Shipment Weight

- **Finding #1**: $W_r^A \perp I \mid W_r^P$ (conditional independency in other information)
- **Finding #2**: $W_r^A \perp W_s^A$ (independency between different shipments)

- **Finding #2**: $W_r^A = W_r^P \cdot \text{Ratio}$

\[
\begin{align*}
\text{Ratio} & = R \\
\text{Mean} & = 0.96 \\
\text{Std.} & = 0.58
\end{align*}
\]
Predicting Shipment Weight

- **Finding #1:** \( W_r^A \perp I \mid W_r^P \) (conditional independency in other information)
- **Assumption:** \( W_r^A \perp W_s^A \) (independency between different shipments)

- **Finding #2:** \( W_r^A = W_r^P \cdot Ratio \)

**Predict:** \( W_r^A = \text{Normal}(0.96 \cdot W_r^P, 0.58 \cdot W_r^P) \)
Predict RouteMap Weight

RouteMap Update
Weight: 84
Flight: AA0613

Predict Route Map Weight

Predictive Model

RouteMap Predicted Weight
Weight: N(84m,84s)
Flight: AA0613

Probabilistic Attribute
Predict Flight Weight

Context: Flight

RouteMap Predicted Weight
Weight: N(84m,84s)
Flight: AA0613

Milestone Update
Weight: 65
Flight: AA0613

Predict Flight Weight

Flight Weight
Weight: sum(Weight)
Planned: sum(Planned)
Flight: AA0613

Probabilistic operation
Alert

Derivation Condition:
\[ \text{Prob}(\text{Weight} > 1.2 \times \text{Planned}) > \delta \]

Flight Weight
Weight: N(750,25)
Flight: AA0613

Alert Over-load

Over-load Alert
Planned: 620
Expected deviation: 130

DEBS 2013, Arlington, TX
The Event Processing Network

- Cargo 2000 System
  - Milestone Update
  - Route Map Update
  - Predict Route Map Weight
  - Predict Flight Weight
  - Alert Hi\(\backslash\)Lo-show
  - Dashboard

- Filter milestone
- Split Flights
- Flights
Experimental Study

Repeated for various $\delta_{\text{Over}} \setminus \delta_{\text{Under}}$

151,000 transports

Operational Dataset
Experimental Study

Repeated for various $\delta^{\text{Over}} \setminus \delta^{\text{Under}}$

151,000 transports

Operational Dataset

80% 20%

Training Dataset Test Dataset
Experimental Study

Repeated for various $\delta^{\text{Over}} \setminus \delta^{\text{Under}}$

151,000 transports

Operational Dataset

Training Dataset

Test Dataset

Model Learning
Experimental Study

Repeated for various $\delta^{\text{Over}} \setminus \delta^{\text{Under}}$

151,000 transports
Operational Dataset

80%
Training Dataset

20%
Test Dataset

Event-driven simulation

Model Learning

DEBS 2013, Arlington, TX
Performance Measures

\[ \text{Recall} = \frac{\text{Alerted}^* \cap \text{Actual}^*}{\text{Actual}^*} \]

\[ \text{Precision} = \frac{\text{Alerted}^* \cap \text{Actual}^*}{\text{Alerted}^*} \]

- **Alerted***: Flights alerted “*-loaded” by the proactive engine
- **Actual***: Flights eventually found “*-loaded”
- **Actual\text{Hi}** – 586; **Actual\text{Lo}** - 532

* = Over\Under
Results - Recall vs. Precision

Over-load

Under-load
Results - Offset Time

- Time passed between alert and flight departure

![Histogram showing mean offset time]

Mean = 2.5 days
85% > 1 day
Summary

- Extension of CEP with uncertainty handling and probabilistic rules is shown to proactively
  - Alert on flight over\under- load with good accuracy, while
  - Allowing sufficient time for a proper reaction

- Discrepancies prediction can be improved
  - Customer Information
  - Product Information, etc.

- Proactive alerting is only the beginning
  - Actions recommendation and execution
  - Optimized with respect to revenue, efficiency, …
Summary

- Extension of CEP with uncertainty handling and probabilistic rules is shown to proactively
  - Alert on flight over\under-load with good accuracy, while
  - Allowing sufficient time for a proper reaction

- Discrepancies prediction can be improved
  - Customer Information
  - Product Information, etc.

- Proactive alerting is only the beginning
  - Actions recommendation and execution
  - Optimized with respect to revenue, efficiency, …

Thanks!