New insights on non-linear delay causation network for passengers and flights in Europe

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Roadmap to combining complex networks, machine learning and delay analysis

1 - motivation
2 - tools & data
3 - results
4 - potential
Reactionary delays:
Delay caused by late arrival of aircraft from previous journeys

Initial delay

Minimum turnover time,
Slot allocation strategy,
Crew/passengers connections,
Sector congestion, etc.

Affects passengers too!
Reactionary delays:
Delay caused by late arrival of aircraft from previous journeys

% Share of Code 93 Rotational Reactionary Delay as Total of All-Causes Delay

CODA digest 2016

CODA digest 2017
Why can’t we efficiently mitigate delay propagation?

“More is different”

Contain hidden information about the real dynamics of the system

**Objective**
Discover the structure created by delay propagation
Both direct and indirect connections
Previous work


PaxIS (IATA ticket) pax data + Individual flights (PRISME traffic data)

200 airports
30,000 flights
2.5 million pax
What are we measuring?
Granger Causality

Measure assessing if a time series “drives” (is causal to) a second one

<table>
<thead>
<tr>
<th>Axiom</th>
<th>Statement</th>
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<tbody>
<tr>
<td>1</td>
<td>Cause must precede the effect in time</td>
</tr>
<tr>
<td>2</td>
<td>Information relating to a cause’s past must improve the prediction of the effect above and beyond information contained in the collective past of all other measured variables (including the effect). Mathematically</td>
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\[
\sigma^2(B \mid U^-) < \sigma^2(B \mid U^−\setminus X^-)
\]
How can we catch more information from the interactions?
Neural Network Causality

\[ y_i = y_{i-1} + x_{i-1} + x_{i-2} \]
\[ Y_t = g(X_{t-1}) + \epsilon \]
Linear case

Non-Linear case
Boosted Neural Network Causality
RESULTS
Network obtained from flight delays

Network obtained from passenger delays
<table>
<thead>
<tr>
<th>Metric</th>
<th>Flight Network</th>
<th>Passenger Network</th>
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<tbody>
<tr>
<td>Link density</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>Transitivity</td>
<td>0.33 (1.26)</td>
<td>0.22 (1.2)</td>
</tr>
<tr>
<td>Assortativity</td>
<td>0.005</td>
<td>-0.07</td>
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<tr>
<td>Efficiency</td>
<td>0.6 (0.96)</td>
<td>0.54 (0.98)</td>
</tr>
<tr>
<td>Entropy</td>
<td>4.40</td>
<td>3.95</td>
</tr>
<tr>
<td>Modularity</td>
<td>0.11</td>
<td>0.16</td>
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</tbody>
</table>
**Figure 3** — Out-bound degree in function of in-bound degree for all airports in the flight network (top panel) and Passenger network (bottom panel). Linear regressions are added in red.

**Figure 4** — Node’s eigenvector centrality of flight Network in function of the average flight traffic of the airport it represents (top panel). Node’s eigenvector centrality of passenger Network in function of the average passenger traffic of the airport it represents (bottom panel).
Use a ‘what-if’ simulator. Solutions might affect differently both networks.
Conclusions
Message to get home
Ideas to think about
Passenger matters

Data matters equally as it contains different information about the overall system

Metrics/tools matter

https://gitlab.com/SBINX/NNC

Simulators help to test mitigation strategies - stakeholders to give data after seeing good results?

SafeClouds.eu
Thank you