Statistical Regularities in ATM: Network Properties, Trajectory Deviations, and Delays

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ELSA
Empirically grounded agent based models for the future ATM scenario
Empirically grounded agent based models for the future ATM scenario
Aim

Build an Agent-Based Model integrating many actors at different levels in order to test new scenarios in ATM.
Presentation of ELSA

Aim
Build an Agent-Based Model integrating many actors at different levels in order to test new scenarios in ATM.

Steps
- Extract statistical regularities and stylized facts from traffic data,
- build the ABM,
- use regularities for calibrating and validating the future ABM.

Here we present a selection of empirical results extracted from the data.
Data and Database

Data...
- on trajectories: M1 (last filled flight plan) and M3 (trajectories updated by radar track) files containing sequences of navpoints,
- on the structure of Airspace (NEVAC files): sectors, routes, etc,
- for 16 AIRAC cycles \(\approx 1\) year and three months.

Database...
- eliminating redundancies,
- allowing very fast query on huge amount of data,
- building data of higher level (measure of complexity...).
Outline

1 Airports
   • Network
   • Strength/degree distributions
   • Network communities
   • Dynamics

2 Sectors
   • Network
   • Dynamics
   • Deviations

3 Navigation points
   • Communities
   • Deviations
AIRPORTS
Airports: Network

Properties of nodes:
- Degree: number of destinations from/to the airport
- Strength: number of flights from/to the airport
Properties of nodes

- Degree: number of destination from/to the airport
- Strength: number of flights from/to the airport
Airports: Network

Size proportional to degree.
Scale free network

- Presence of hubs,
- very short path between any points in the network ($\sim 3$).
Betweenness centrality

Measure of how much the node is central in the network \( \simeq \) number of shortest path passing through it.
Airports: communities

General purpose/methods

- Communities are group of nodes which are mutually more highly interconnected than they are with the rest of the network.
- Many algorithms have been proposed to partition a network in communities:
  - Maximization of modularity: finds the partition that maximizes modularity, which is the fraction of the links within the given communities minus the expected such fraction if links were distributed at random (under some null hypothesis);
  - Infomap: based on random walks on networks,
- After a partition has been obtained, one can characterize each community by measuring the over-expression of a given node attribute.
Airports: communities

day 2010-05-10, airac 334, blondel
Big supra national communities $\Rightarrow$ tool to design airspaces?
Number of flights and active airports are changing on a daily basis, yearly basis and because of external shocks (volcano).
## Airports: dynamics

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Sectors
Sectors: structure

3D View of a sector

Side view of a sector

Airblocks

Sector

A sector slices one or more airblocks at different heights.
Sectors: structure
Sectors: network
Sectors: strength and degree

Non scale-free network
- typical degree, strength, length...
- big diameter.
Sectors: dynamics

Structure of the network is changing during the day.
- Change of the traffic on the network,
- change of the underlying network (geographical neighbours of sectors).
The change in the structure allows to absorb the traffic without more reroutings.
NAVIGATION POINTS
Finer scale, geographical network.
Navpoints: communities

[Map showing communities with different colors indicating varying levels of some metric.]
Navpoints: communities

Infomap

Big communities, looking like airspaces: ACC?
Navpoints: communities

Big communities, looking like airspaces: ACC? ⇒ tool to design airspaces?
Local metrics

- Number of flights deviated,
- point common in M1 (planned trajectory) and M3 (actual trajectory),
- area generated,
- etc...
Number of horizontal deviations drops with local traffic.

Number of vertical deviations increases with local traffic.
Nodes of low degree are more avoided when the traffic increases.
Nodes of high degree are more avoided when the traffic decreases.
Nodes of low degree gets flights more delayed when the traffic decreases.
Nodes of high degree gets flights more delayed when the traffic increases.
Conclusion

Airport Network
- Scale-free network (small world),
- different type of network for companies,
- organized in communities which look like the FABs.

Sector Network
- Geographical network,
- dynamical structure on top of dynamical conditions (traffic).

Navpoint Network
- Finer scale, geographical network,
- organized in communities which look like the ACCs,
- Deviations are handled differently at high degree nodes and low degree nodes.
Thanks for your attention