

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

SID 2012 – Braunschweig, 27th of November, 2012



S. VITALI, G. GURTNER, L. VALORI , M. CIPOLLA, V. BEATO, S.
POZZI, S. MICCICHÈ, F. LILLO & R. MANTEGNA

ELSA

Empirically grounded agent based models for the future ATM scenario

Empirically grounded agent based models for the future ATM scenario

DEEP BLUE
Valentina Beato
Simone Pozzi



UNIVERSITÀ DI
PALERMO
Stefania Vitali
Marco Cipolla
Salvatore Miccichè
Rosario Mantegna



SCUOLA NORMALE
SUPERIORE
Luca Valori
Gérald Gurtner
Fabrizio Lillo





Aim

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



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...

- ... 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 $\simeq$ 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...).



1 Airports

- Network
- Strength/degree distributions
- Network communities
- Dynamics

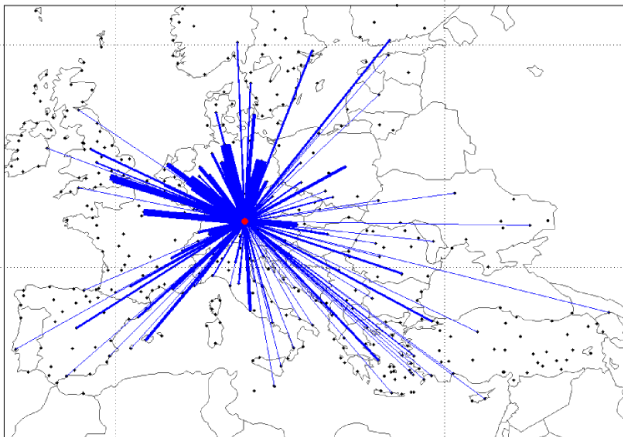
2 Sectors

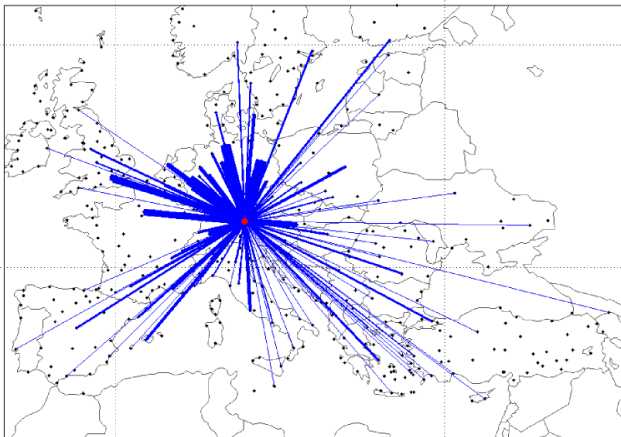
- Network
- Dynamics
- Deviations

3 Navigation points

- Communities
- Deviations

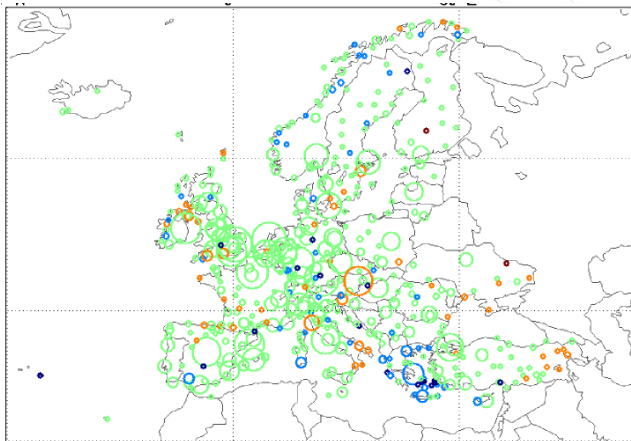
AIRPORTS



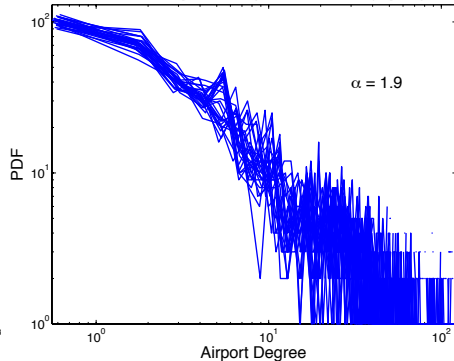
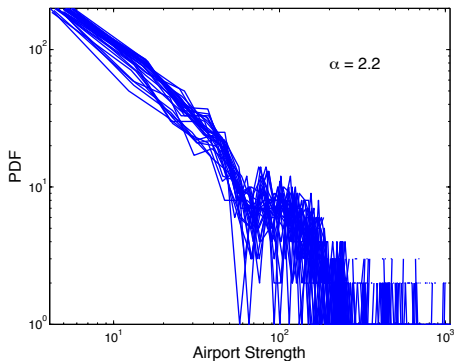


Properties of nodes

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

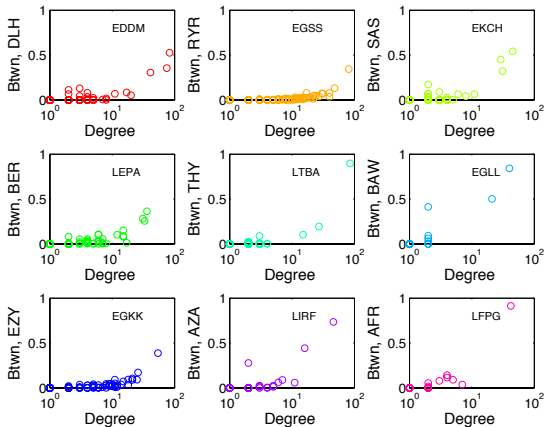


Size proportional to degree.



Scale free network

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

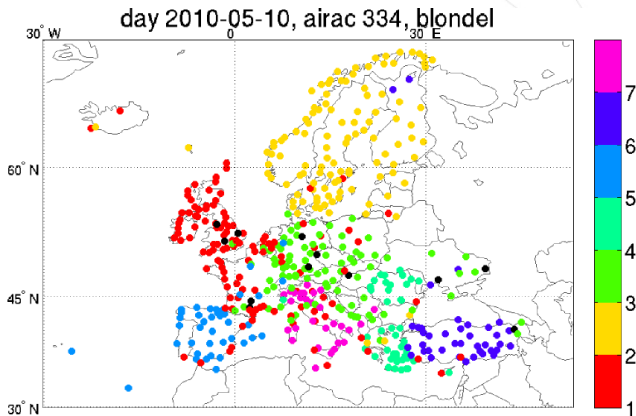


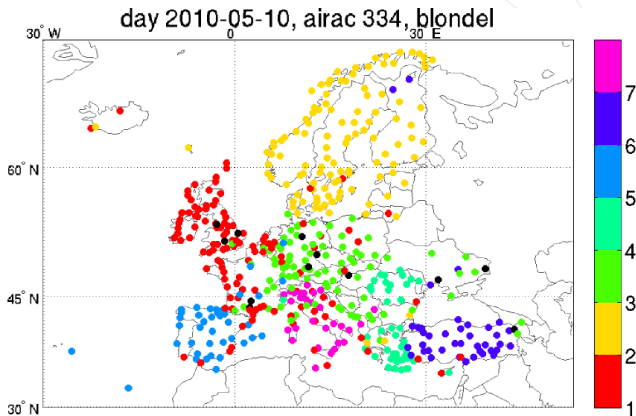
Betweenness centrality

Measure of how much the node is central in the network $\simeq$ number of shortest path passing through it.

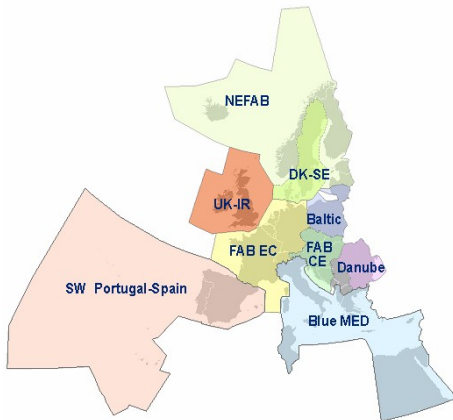
General purpose/methods

- 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:
 - 1 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);
 - 2 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.

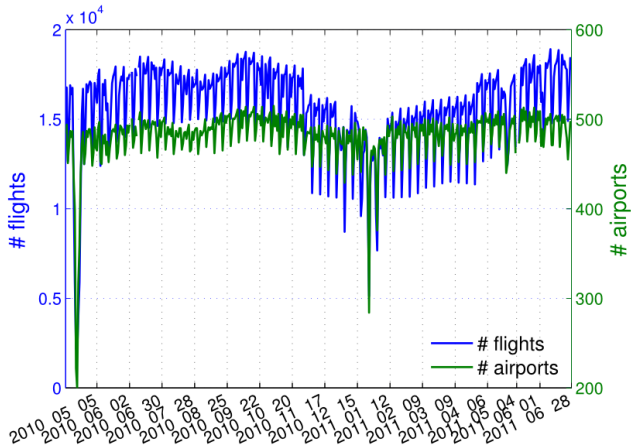




Big supra national communities



Big supra national communities $\Rightarrow$ tool to design airspaces?



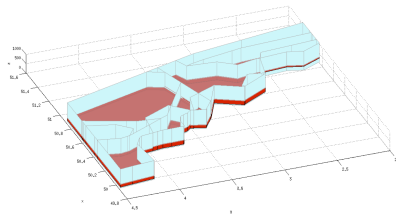
Seasonality

Number of flights and active airports are changing on a daily basis, yearly basis and because of external shocks (volcano).

Monday 13/05/2010			Sunday 19/05/2010		
Cluster	overexpressed attribute	size	Cluster	overexpressed attribute	size
1	uk	121	1	norway	107
1	ireland	121	1	sweden	107
1	france	121	1	finland	107
2	norway	113	1	denmark	107
2	sweden	113	2	uk	104
2	finland	113	2	ireland	104
2	denmark	113	3	germany-civil	97
3	germany-civil	89	3	austria	97
3	poland	89	3	romania	97
3	austria	89	4	spain	51
4	greece	45	4	portugal	51
4	romania	39	5	turkey	40
5	spain	39	6	italy	36
5	portugal	39	7	greece	32
6	turkey	34			
7	italy	27			

SECTORS

3D View of a sector

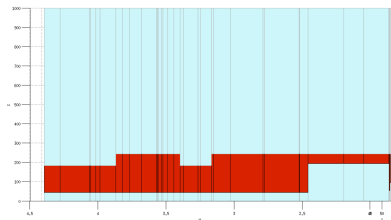


Airblocks

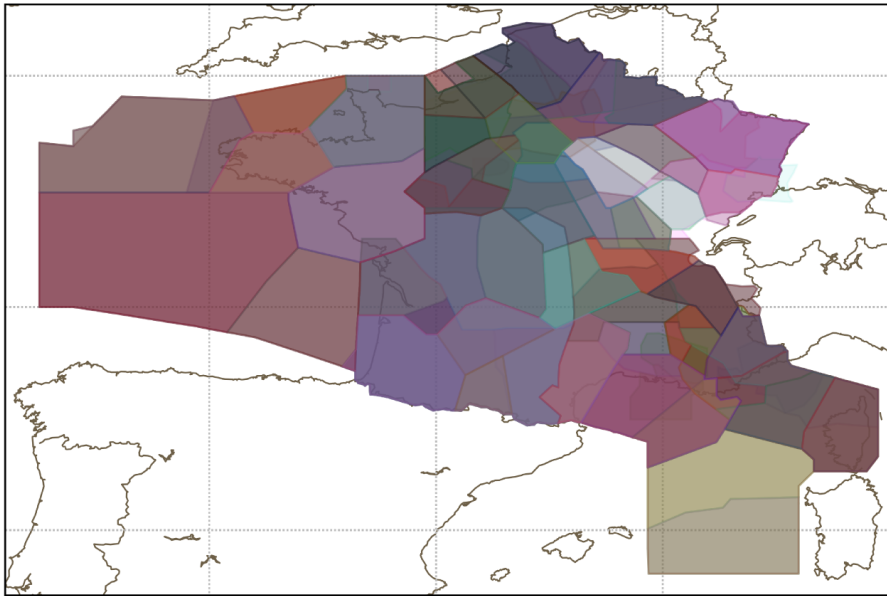


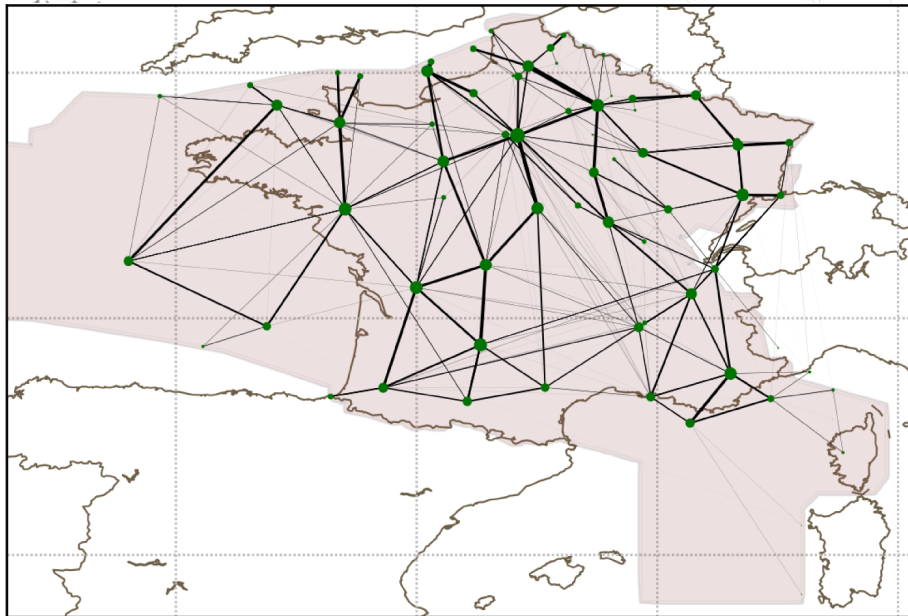
Sector

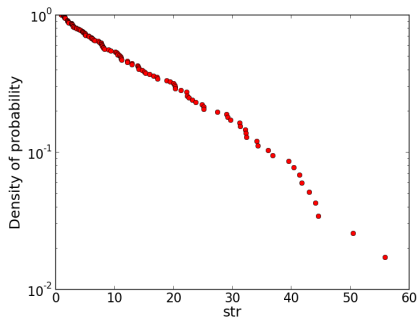
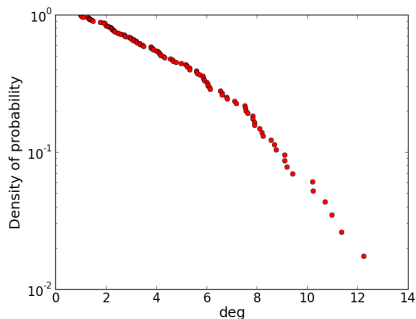
Side view of a sector



A sector slices one or more airblocks at different heights.

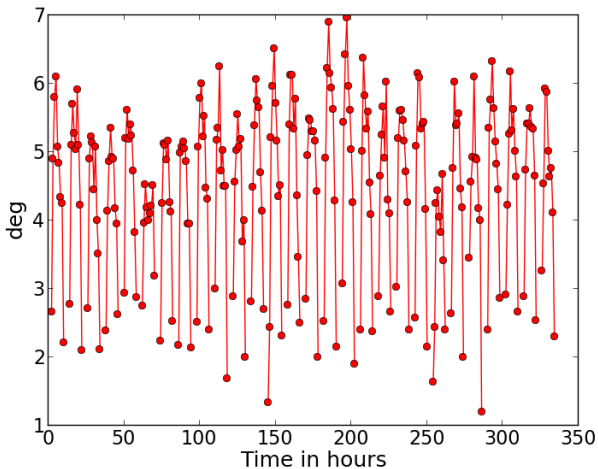




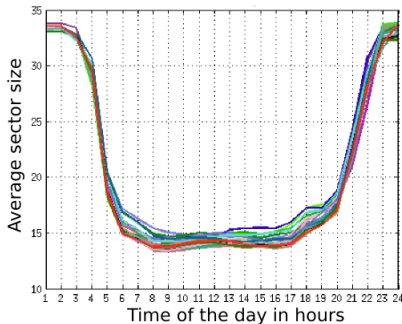
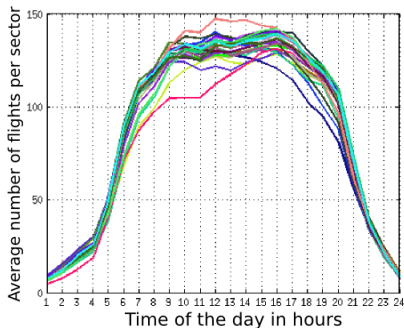


Non scale-free network

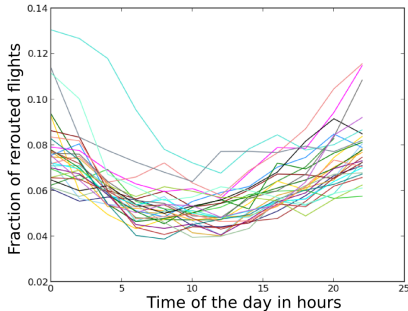
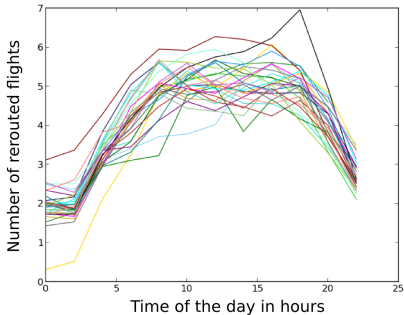
- typical degree, strength, length...
- big diameter.



Structure of the network is changing during the day.



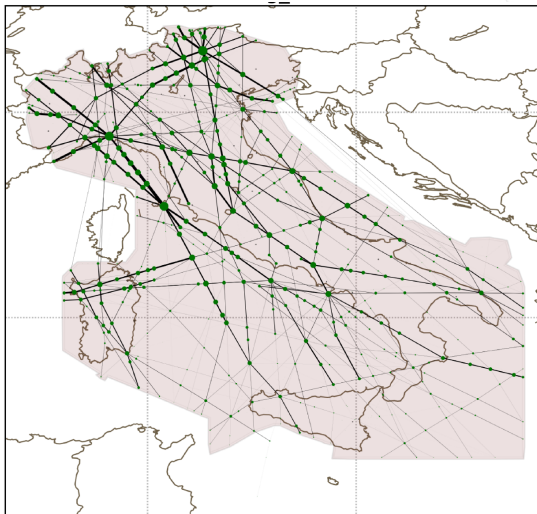
- Change of the traffic on the network,
- change of the underlying network (geographical neighbours of sectors).



The change in the structure allows to absorb the traffic without more reroutings.

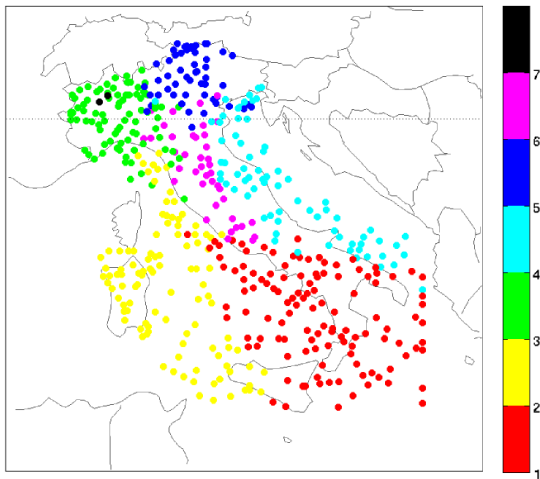
NAVIGATION POINTS

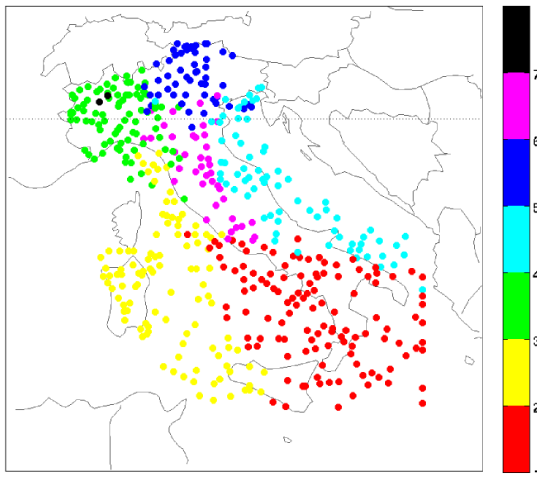
Navpoints: map



Finer scale, geographical network.

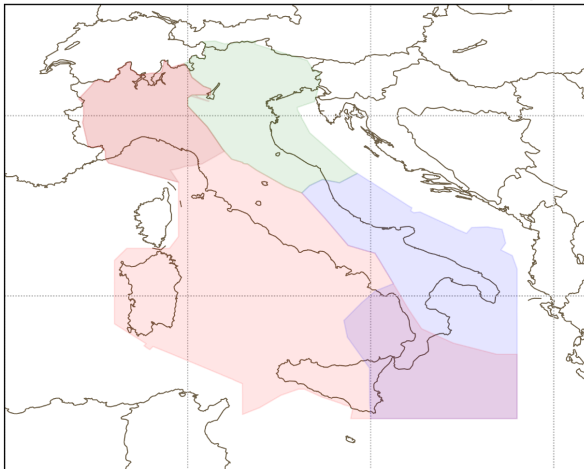
Navpoints: communities





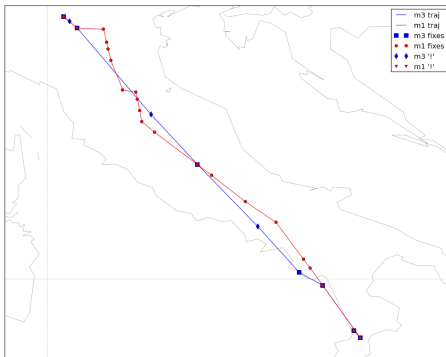
Infomap

Big communities, looking like airspaces: ACC?



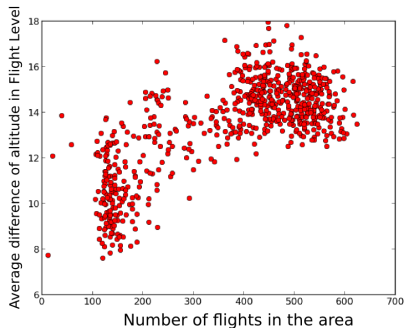
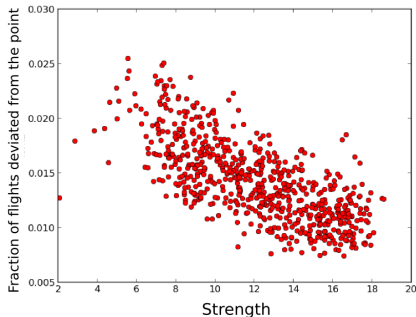
Infomap

Big communities, looking like airspaces: ACC? $\Rightarrow$ tool to design airspaces?

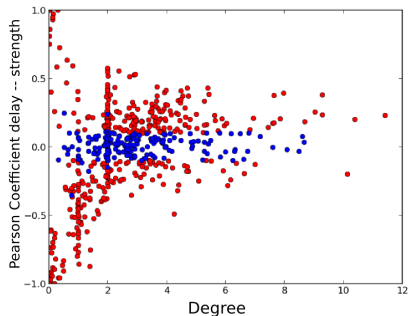
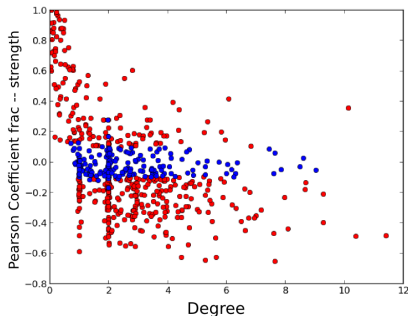


Local metrics

- 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



DEEP BLUE
Valentina Beato
Simone Pozzi



UNIVERSITÀ DI
PALERMO
Stefania Vitali
Marco Cipolla
Salvatore Miccichè
Rosario Mantegna



SCUOLA NORMALE
SUPERIORE
Luca Valori
Gérald Gurtner
Fabrizio Lillo

