Escuela AI HUB de verano
Sobre IA y Educación

Sistemas de Multiagentes

José Javier Ramasco
IFISC(CSIC-UIB)

CSIC Consejo Superior de Investigaciones Científicas | CSIC HUB Inteligencia Artificial
Fundación "la Caixa"
IFIC Institut de Física Corpuscular
Vniversitat de València

Multigent systems and their relation to AI?

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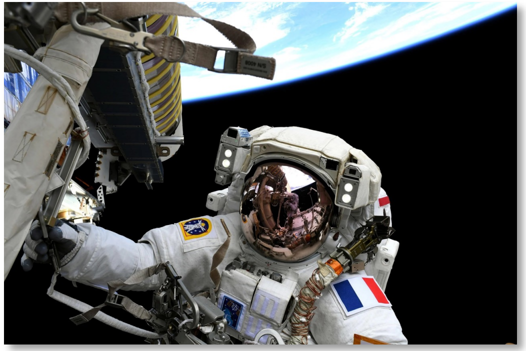
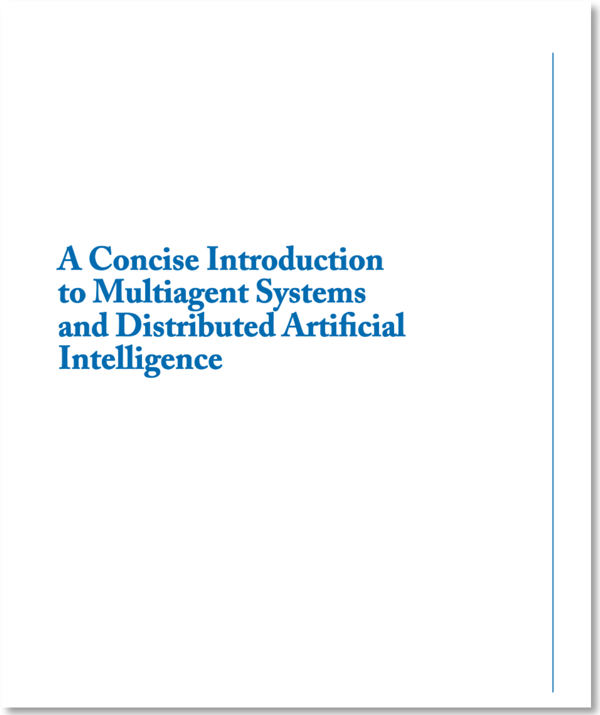
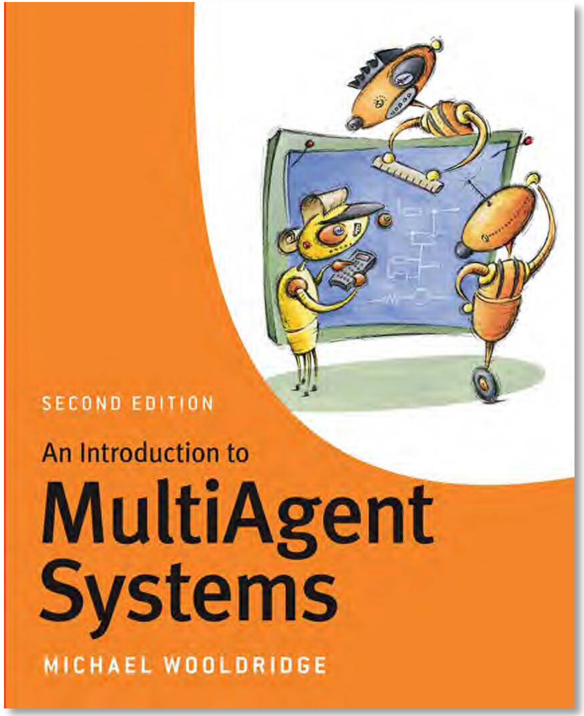
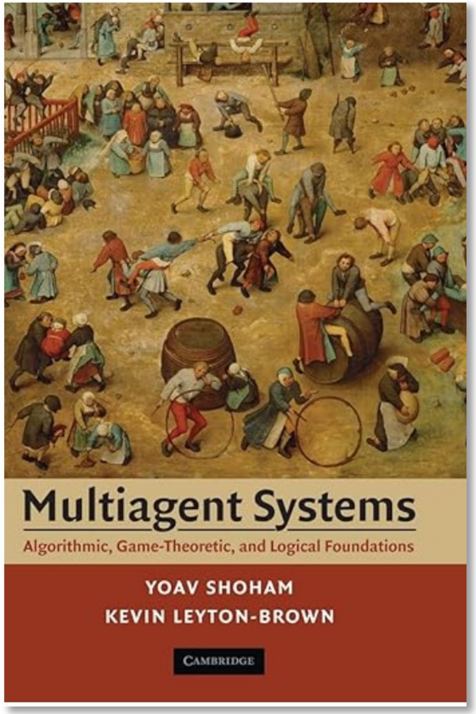


Some references







Agents

Main Characteristic:

Autonomy, the agents must be autonomous in their actions and decisions.

Environment → Sensing → Decision

→ **Action**

Agents

Agents' features (intelligence?):

- Reactivity to the environment
- Proactiviness, planning to reach a goal
- Social capacities

Agents

Formalizing it:

Environment: $\{e_0, e_1, e_2, e_3, \ldots.\}$

Agents' actions: $\{A_0, A_1, A_2, A_3, \ldots.\}$

Sequence for the model:

$$\{(e_{t=0}, A_{t=0}), (e_{t=1}, A_{t=1}), (e_{t=2}, A_{t=2}), \ldots.\}$$

Agents

Decisions:

The agents must select an action based on the environment:
- state of the environment e_t
- state of the agent: a_t

$$P(A_{t+1}) = f(e_0, e_1, \ldots, e_t, a_0, a_1, \ldots a_t, A_1, \ldots, A_t)$$

Agents

Decisions:

The agents can be

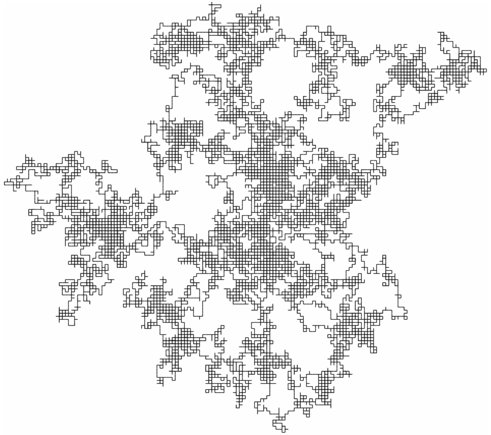
- Reactive:

$$P(A_{t+1}) = f(e_0, e_1, \ldots, e_t)$$

- "Planning" with a goal: they have a payoff function that attempt to optimize.

Agents

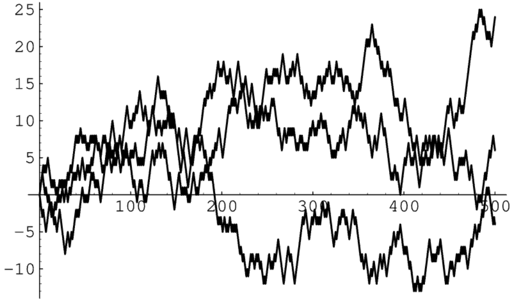
Memory:



- Infinite memory:

$$P(A_{t+1}) = f(e_0, e_1, \ldots ,e_t, a_0, a_1, \ldots a_t, A_1, \ldots, A_t)$$

- Markovian: $P(A_{t+1}) = f(e_t, a_t, A_t)$



Agents

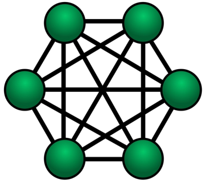
Updates:

- Asynchronous: agent by agent
- Synchronous or Parallel: all the agents update to t+1 at the same time depending on the state of the system in t

Communication

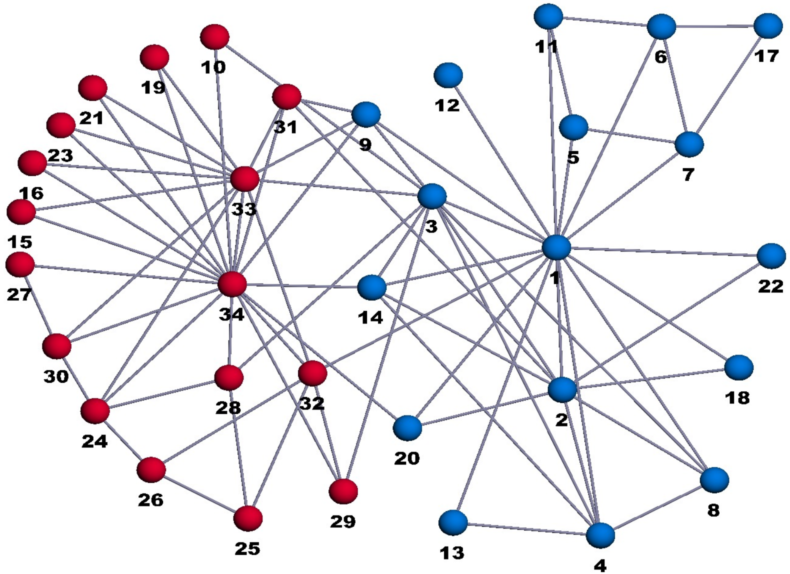
Structure of the communication network:

- All-all, meanfield



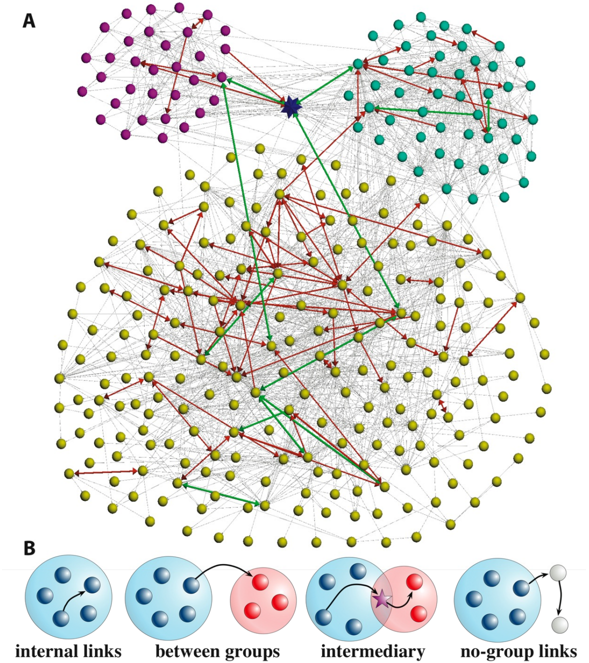
- Global variables

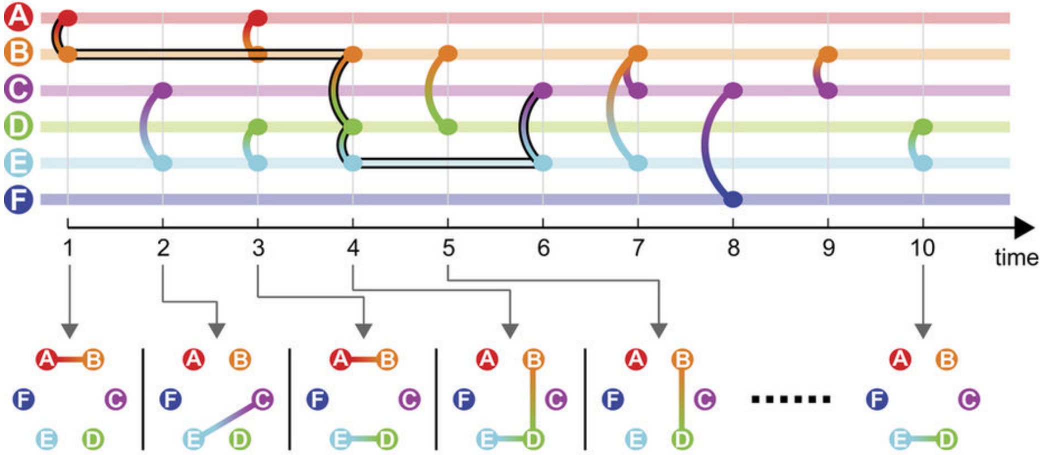
- Network



Communication

Structure of the communication network:





Communication

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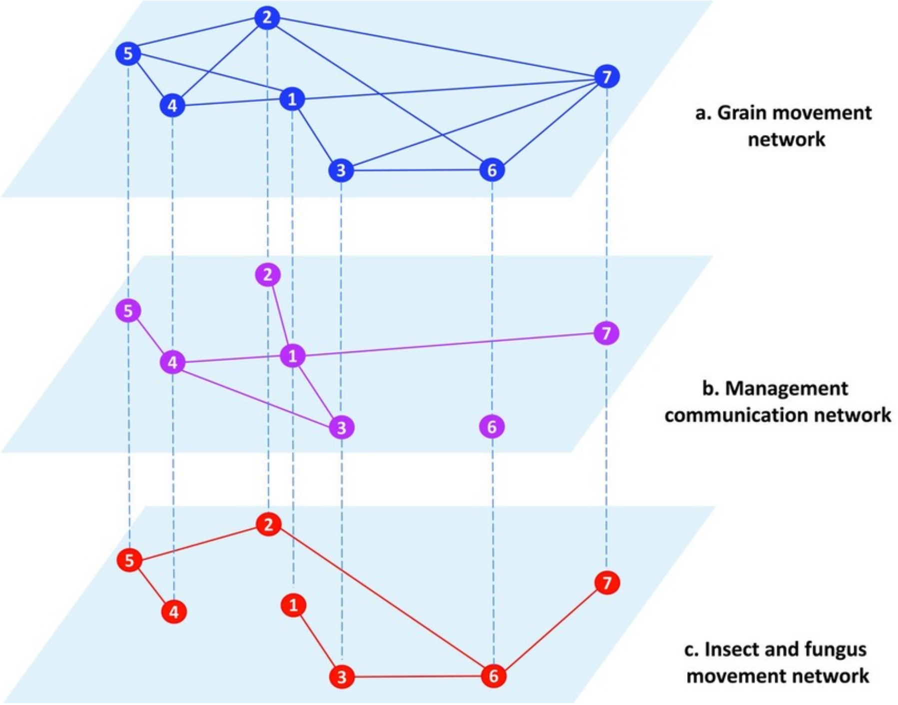
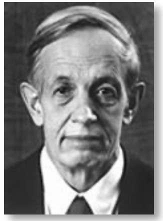


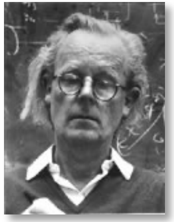
Playing games

John von Neumann y Oskar Morgenstern (1944):
The theory of games and economic behavior
(zero-sum games)

John Nash (1950):
Equilibrium points in n-person games

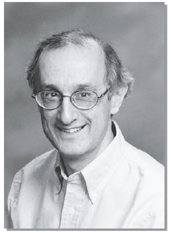


John Maynard Smith (1982):
Evolution and the theory of games
Evolution (biological)



William Hamilton and Robert Axelrod (1981):

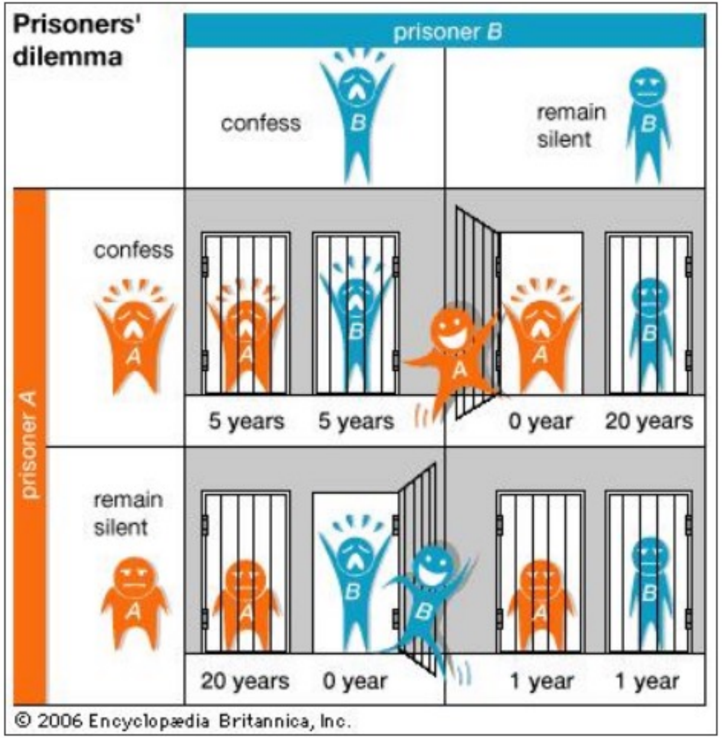
Robert Axelrod (1984):
The Evolution of Cooperation



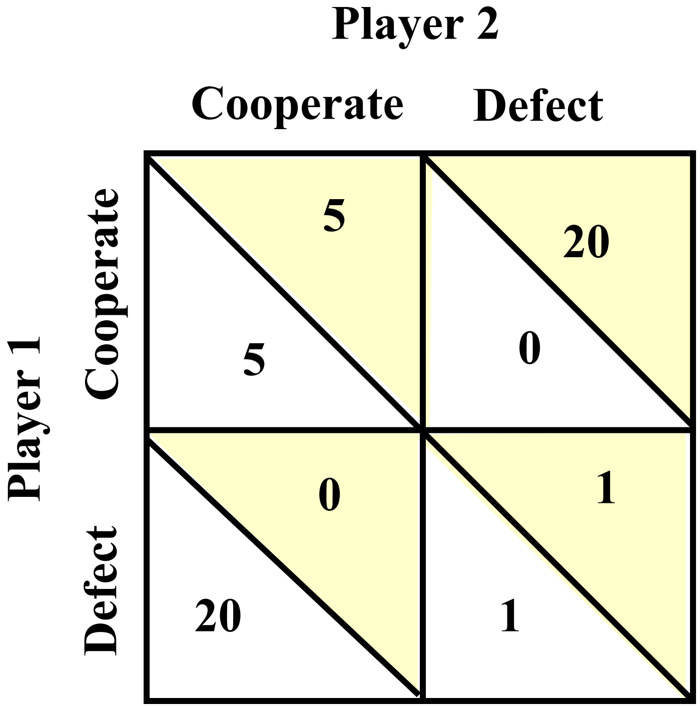
Playing games Ultimatum

Playing games

Prisoner



most famous and influential idea models in the social sciences! (~3,000,000 results on Google Scholar)



Playing games Prisoner

General problem:

- The origin of cooperation.
- Whenever there is a conflict between self-interest and the common good.
- You are tempted to do something, but know it would be a great mistake if everybody did the same thing.

'*The origins of virtue*', Matt Ridley (1996)

Playing games

Nash equilibrium:

•A set of strategies (one per player) from which no player benefits by changing unilaterally

•A set of strategies such that each one of them is a ***best response*** (highest payoff) to the joint strategies of the rest

Ask what each player would do, *taking into account* the decision-making of the others: Each player is told the strategies of the others. Suppose then that each player asks himself or herself: "Knowing the strategies of the other players, and treating the strategies of the other players as set in stone, can I benefit by changing my strategy?"
If any player would answer "Yes", then that set of strategies is not a Nash equilibrium. But if every player prefers not to switch (or is indifferent between switching and not) then the set of strategies is a Nash equilibrium.

The largest pay-off is not necessarily achieved at the Nash equilibrium.

→ A unique Nash equilibrium does not exist for every game

Playing games

John Maynard Smith

Evolutionary version of Game Theory: i) Players not required to be rational
ii) Player required to have a strategy
iii) Multiplayer game

Strategies are not fixed, the **question** is dynamical: ***How strategies are selected on time by interaction?***

Strategy:
Classical theory: players have strategy sets from where to choose their actions
Biology: species have strategy sets from which every individual inherits one

Interactions:
Classical theory: one-shot games and iterated games
Biology: random and repeated pairing of individuals, with strategies based on their genome and not on the past

Equilibria:
Classical theory: Nash equilibrium
Biology: Evolutionary stable strategy (ESS)

Playing games

Axelrod's Prisoner's Dilemma Tournaments

- In the 1980s, Axelrod organized two tournaments and invited many scientists and mathematicians to submit strategies (n-person games).
- The strategies played iterated games against one another in a round-robin fashion.
- Some strategies were quite complicated – e.g., creating complex predictive models of various opponents

Conclusions on best strategies:
- **Be Nice** (never be first to defect)
- **Be Forgiving** (be willing to cooperate if cooperation is offered)
- **Be Retaliatory** (be willing to defect if others defect against you)
- **Be Clear** (be transparent about what your strategy is – make it easy to infer)

And the winner is (Anatole Rapoport)

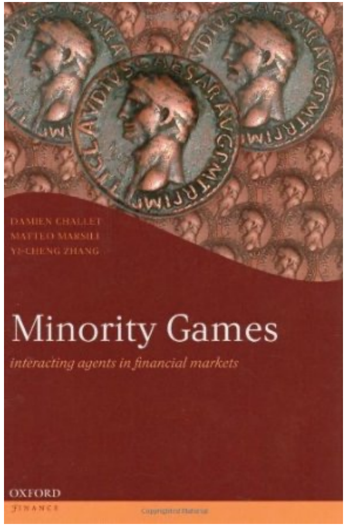
TIT FOR TAT: Start out by cooperating. Then at each successive round, do what the other player did on the previous round.

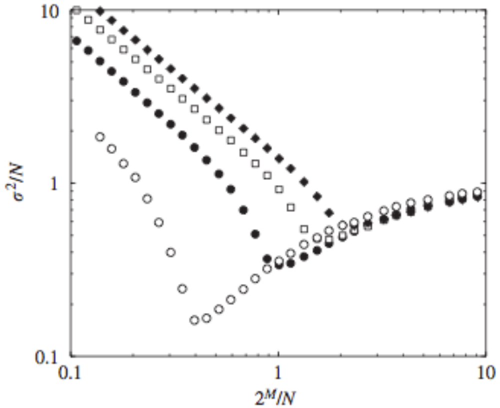
Simplest of all strategies and Nice, Forgiving, Retaliatory, Clear

Playing games

Towards the market: minority game

W. Brian Arthur, “Inductive Reasoning and Bounded Rationality”, American Economic Review **84**, 406 (1994).





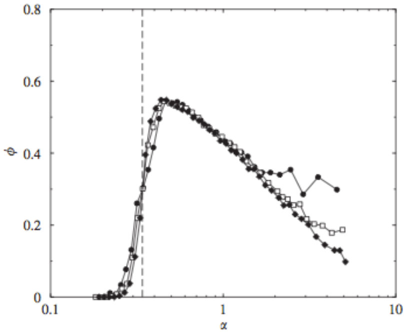
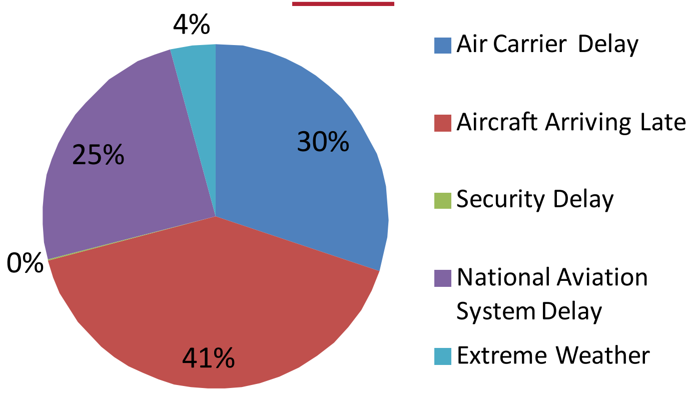


Fig. 3.2 Fraction of frozen agents versus $\alpha = P/N$ for $M = 6$ (circles), 7 (squares), and 8 (diamonds). The critical point is located at the intersection of the three curves.

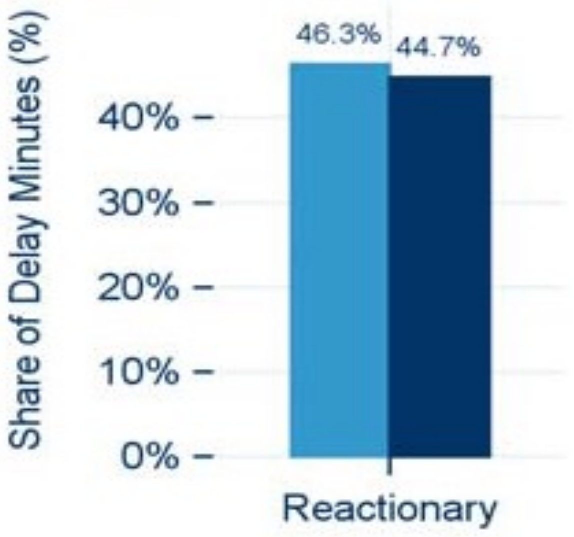
Socio technical systems

Planes and delays

- Total cost of flight delay in US in 2007 was **41B** dollars.
- In the EU, the direct cost is around **2B** euros
- Rich transport dynamics.
- Cascading failure.



(http://www.transtats.bts.gov/)



(http://www.eurocontrol.int)

Socio technical systems

Databases: Planes and delays

- Airline On-Time Performance Data (BTS (USA), CODA Eurocontrol-EU))

- *Schedule & actual departure (arrival) times*
- *Origin & destination airports*
- *Airline id*
- *Tail number*

- 2010 flights (USA):

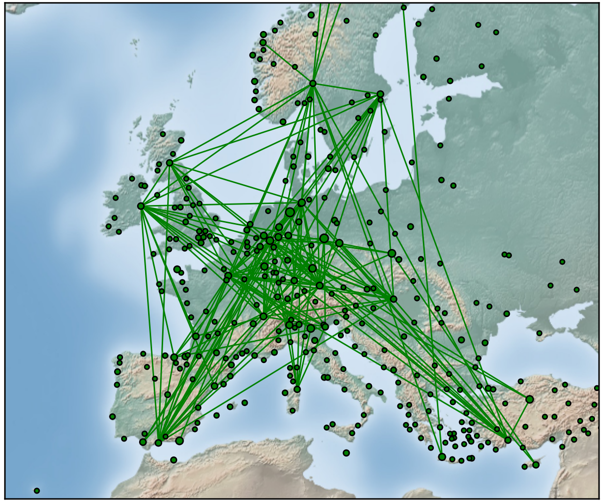
  - *6,450,129 flights (74 %)*
  - *18 carriers*
  - *305 airports*

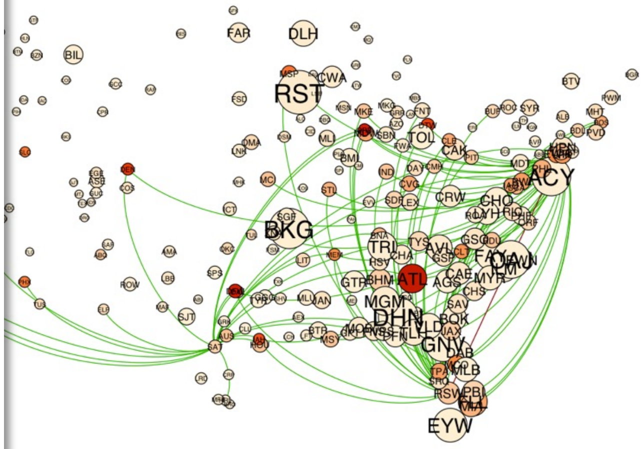
- 2013 flights (EU):

  - *20,000 flights/day*
  - *> 50 carriers*
  - *320 airports*

Network:

- Nodes: airports
- Edges: direct flights between airports
- Node attributes: average delay per flight





Socio technical systems

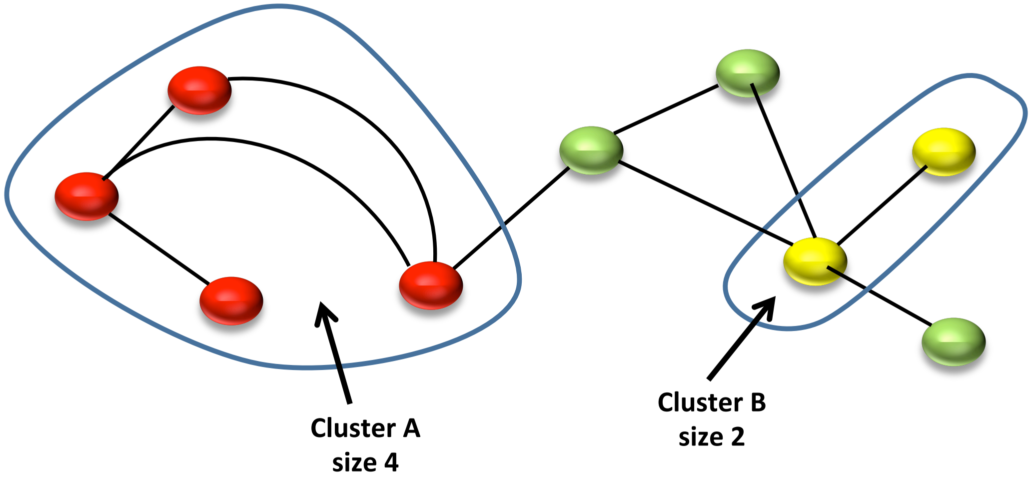
Planes and delays

Clusters:

- Formed by airports in problems
  - ➢ average delay per flight > T min

- Must be connected (flight route between them)

- *A group of airports connected by flights that their average delay is higher than T minutes*

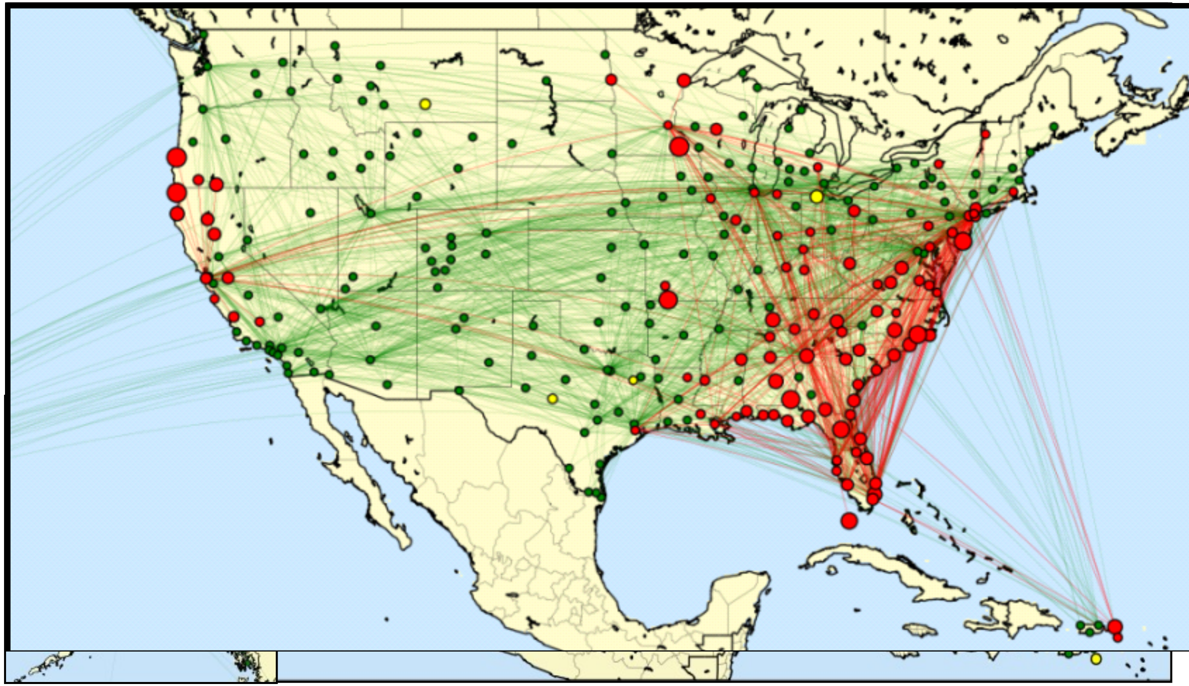


Socio technical systems

Planes and delays

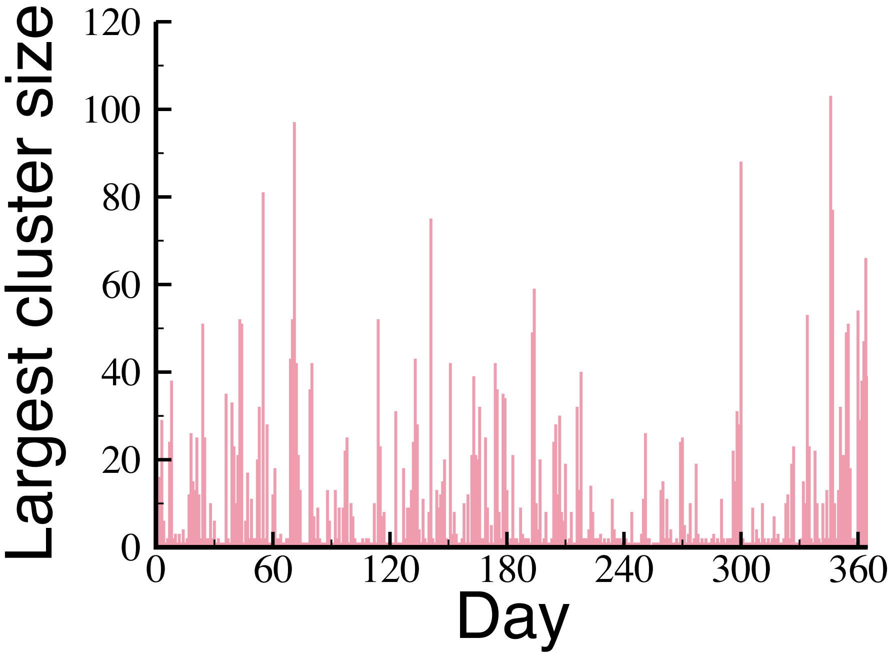
- **March 12, 2010**
- Average delay per delayed flight:

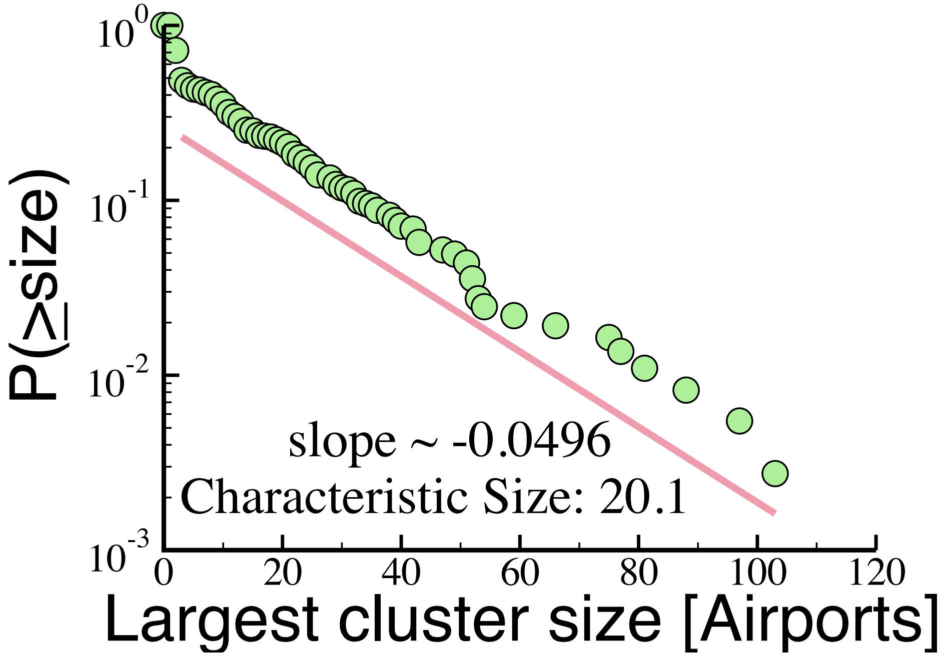
➢ **53.2 min**



Socio technical systems

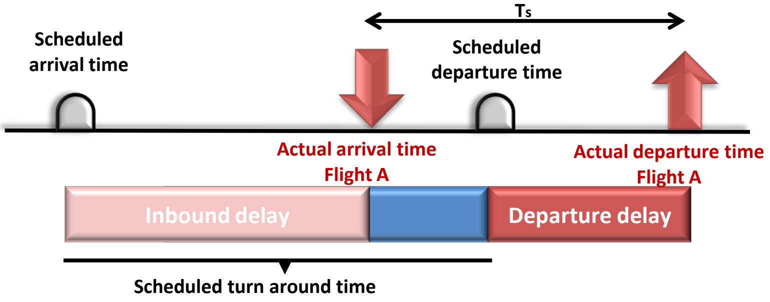
Planes and delays



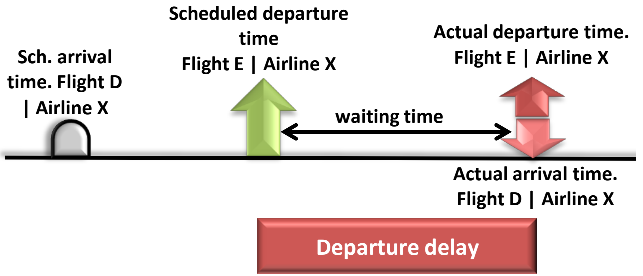


Socio technical systems

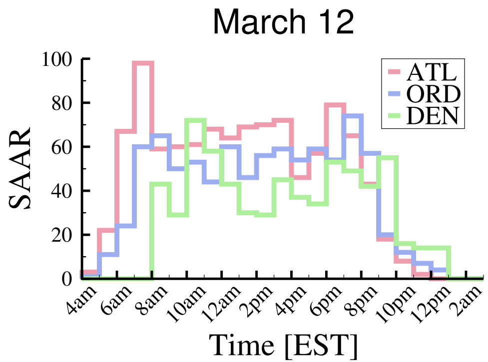
Planes and delays



$$T^j_{\text{act.d}}(p_{ij}) = \max[T^j_{\text{sch.d}}(p_{ij}); T^j_{\text{act.a}}(p_{ij}) + T_{\text{s}}]$$



$$T^j_{\text{act.d}}(p_{ij}) = \max[T^j_{\text{sch.d}}(p_{ij}); T^j_{\text{act.a}}(p_{ij}) + T_{\text{s}}; \max[T^j_{\text{act.a}}(p_{i'j})]], \forall i' \neq i$$



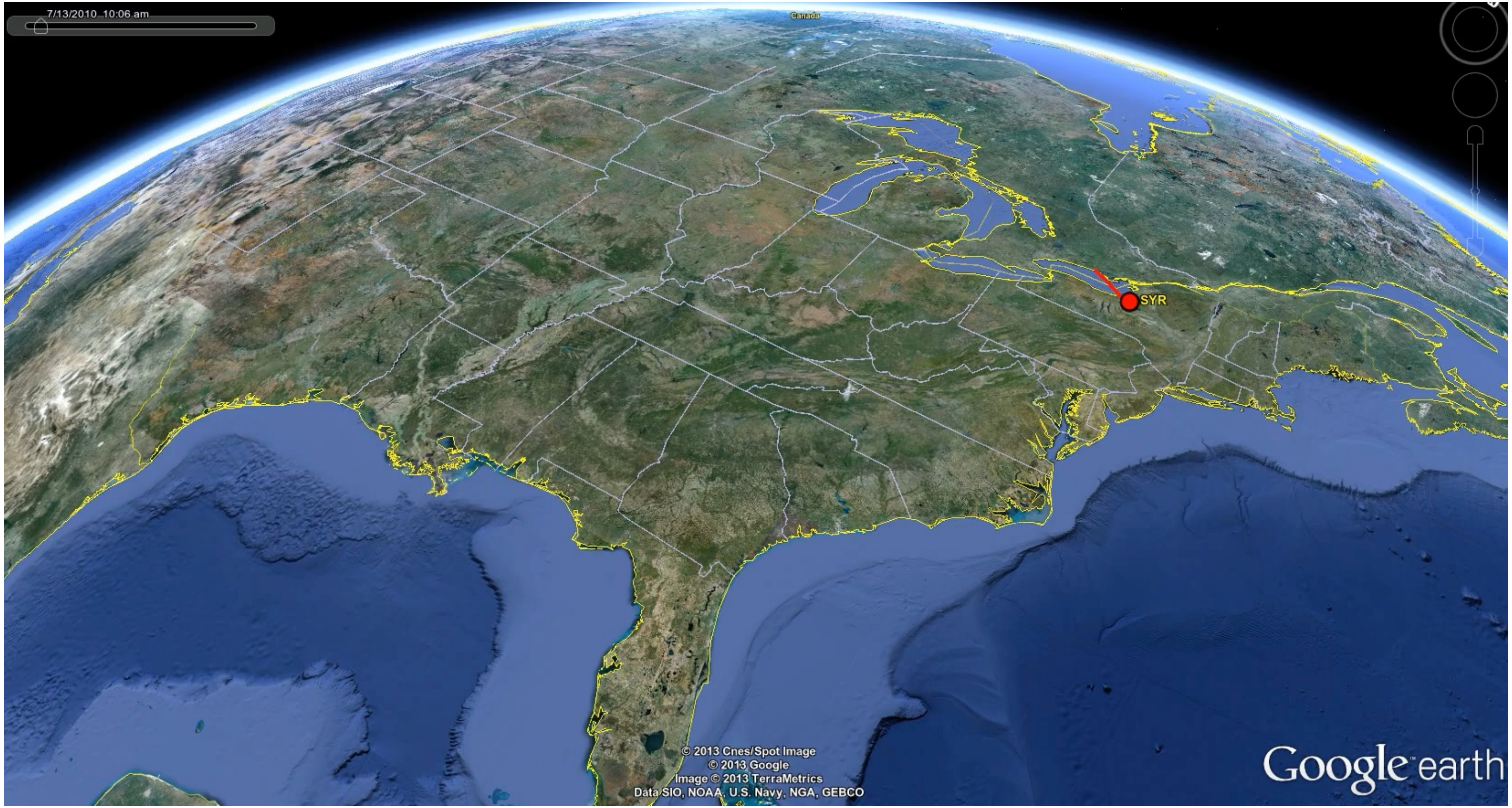
$$T^j_{\text{act.d}}(p_{ij}) = \max[T^j_{\text{sch.d}}(p_{ij}); T^j_{\text{q}}(p_{ij}) + T^j_{\text{act.a}}(p_{ij}) + T_{\text{s}}]$$

Initial Conditions

- *From the data…*
  - Known → when, where and the departure delay for the first flight of the sequence.
- *Random initial conditions…*
  - Fixed initial delay (min)
  - % of initially delayed planes

Socio technical systems

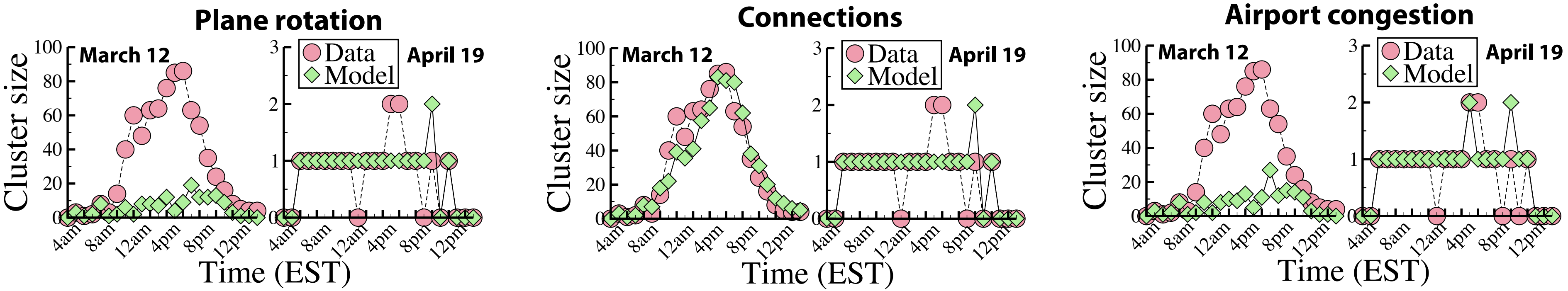
Planes and delays



Socio technical systems

Planes and delays

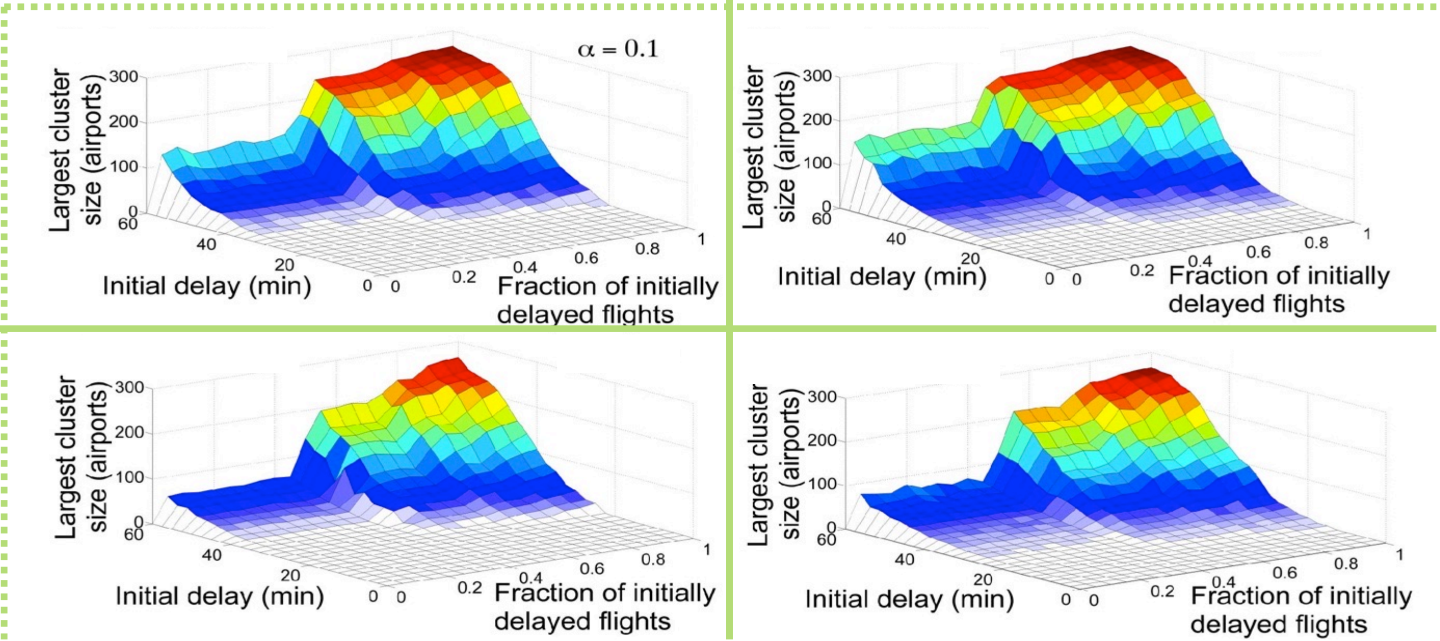
Data and model comparison for March 12 and April 19, 2010



Socio technical systems

Planes and delays

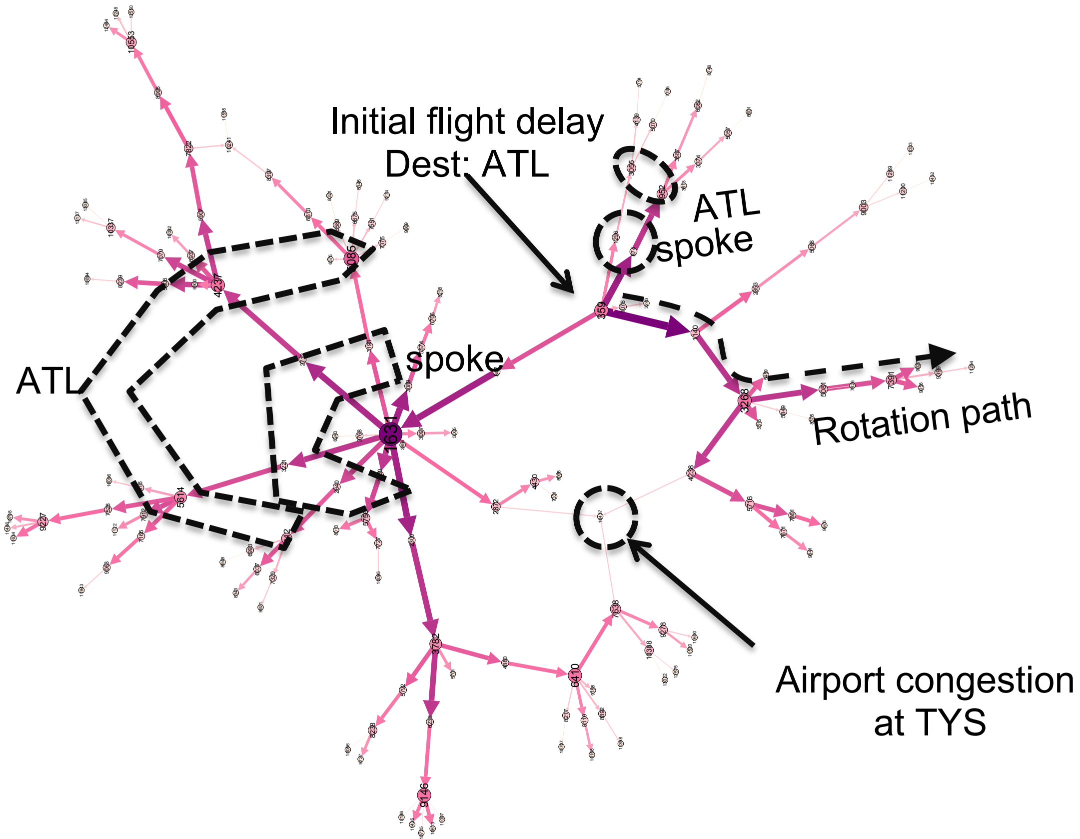
- *With random initial conditions…*



- Each day is potentially a bad day, if some initial conditions are met.
- Flight connectivity is a key factor for the rise of congestion in the network.
- Sensitivity to initial conditions.

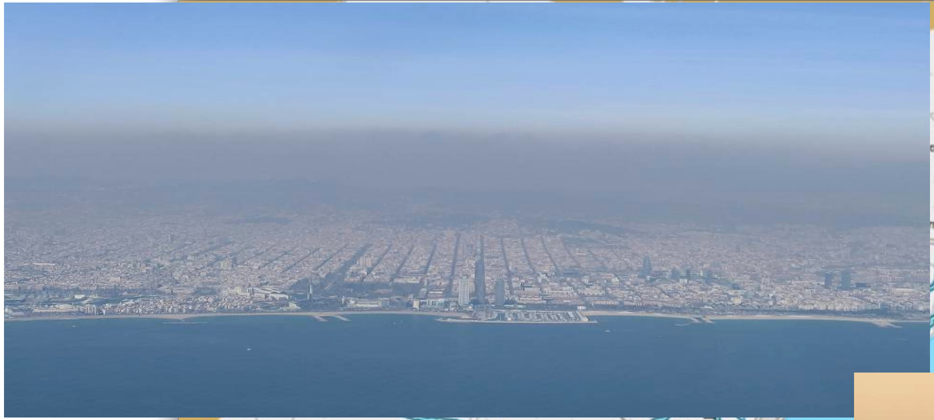
Socio technical systems

Planes and delays



Socio technical systems

Mobility and cities



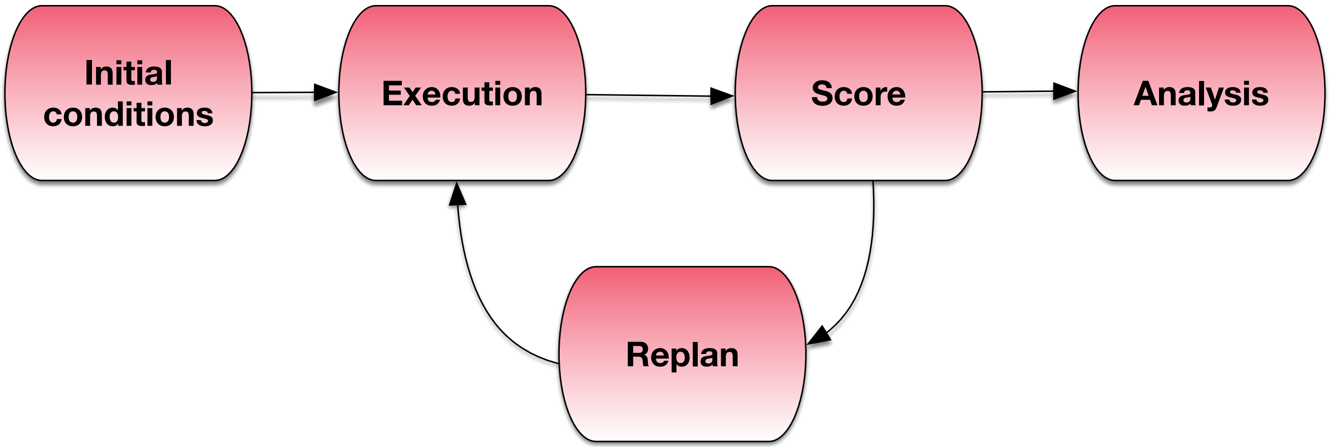
Socio technical systems

Mobility and cities

Socio technical systems

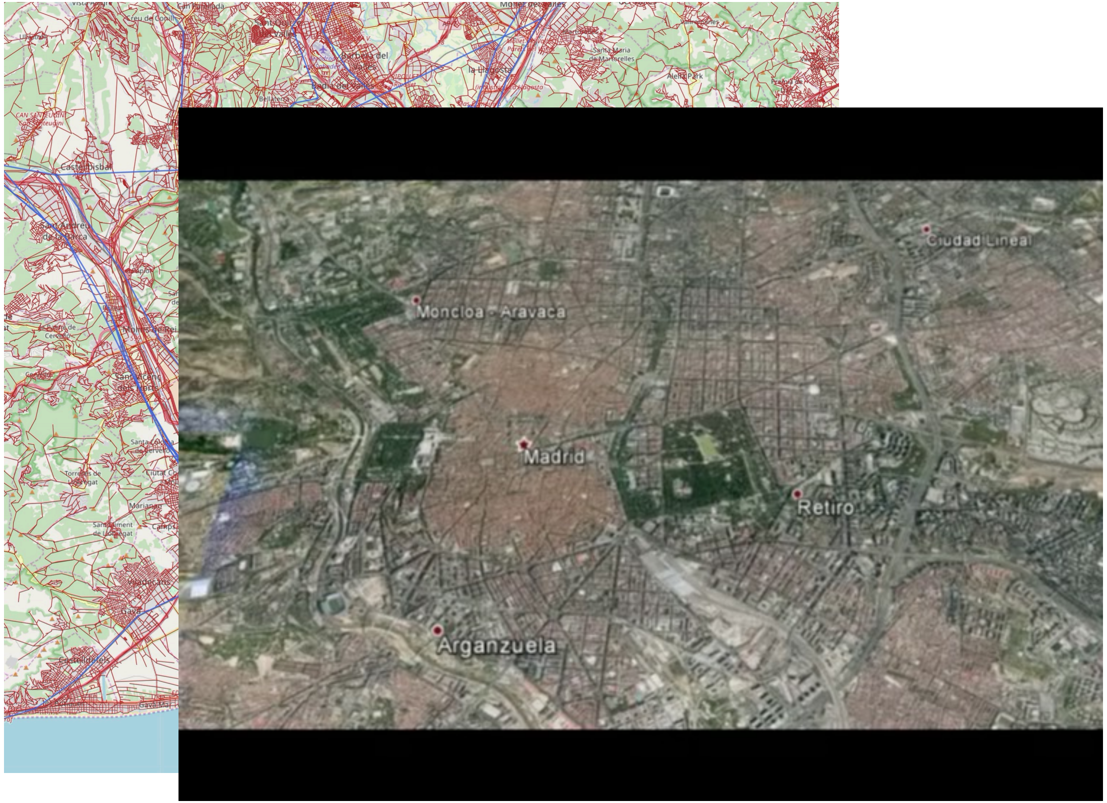
Mobility and cities

MATSIM + Phone users agenda



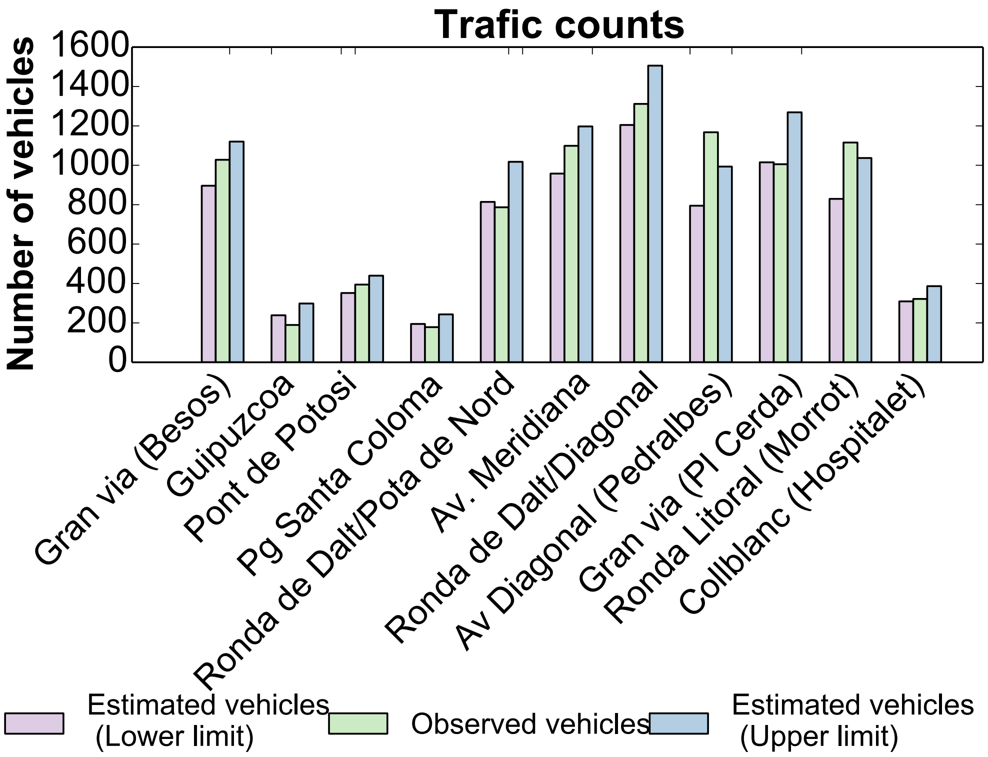
Socio technical systems

Mobility and cities

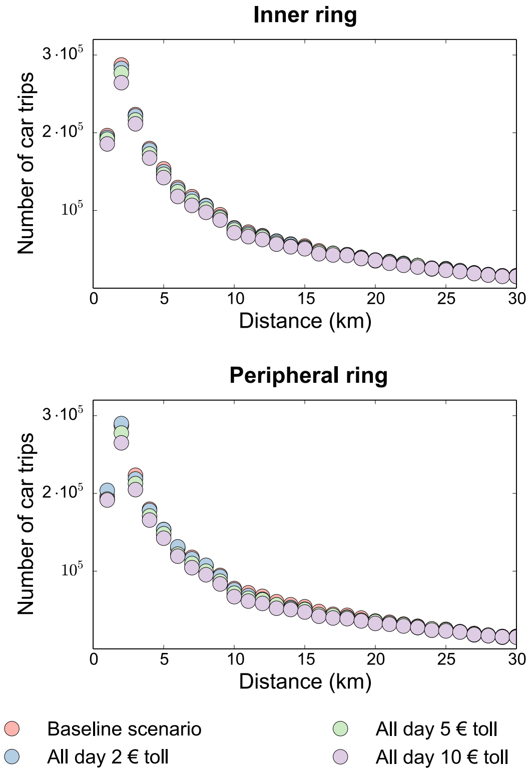


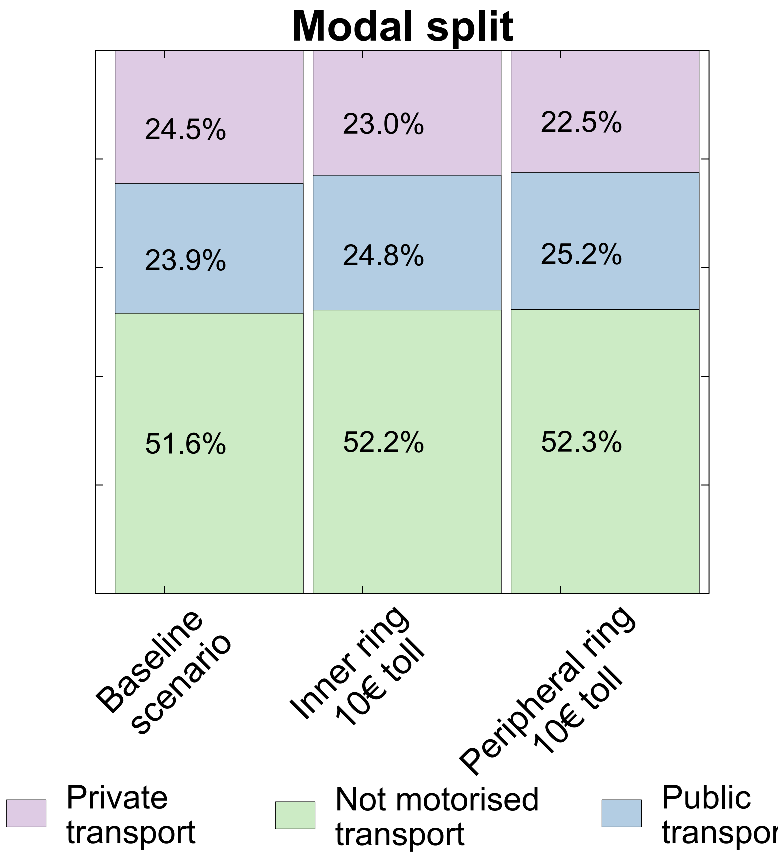
Socio technical systems

Mobility and cities



Socio technical systems





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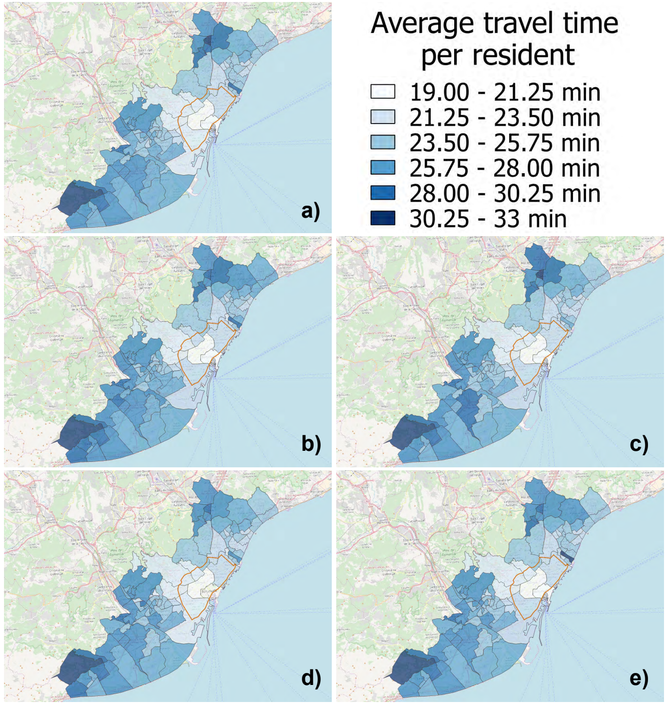
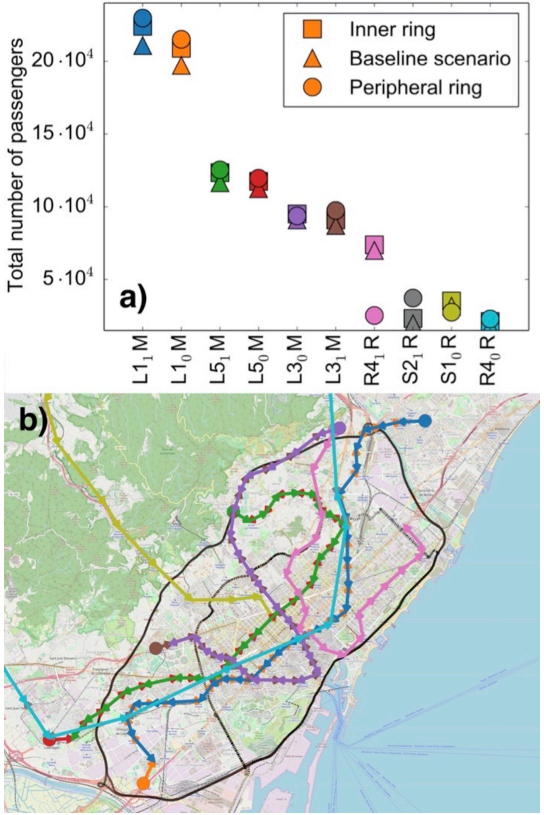
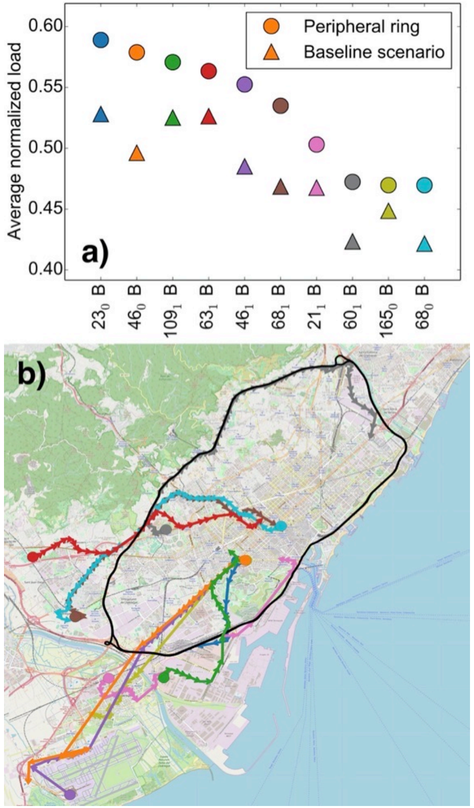
Mobility and cities







Conclusions

- Needs: Data & knowledge on the decision process

- Steps:

  - Agents, communication, decision making
  - Characterization
  - Calibration
  - Validation
  - Scenario analysis