Complex Networks 2025

Final Presentation

Analysis of the European Air Transport Multiplex Network

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Task 2
Complex Networks Analysis

Summary

1. Network Description
2. Mesoscale Analysis: Communities
3. Dynamic Analysis: Random Walks and Synchronization
4. Multiplex Analysis

1 Network Description

- We have been working with the **Air Transportation Multiplex Dataset**.
  - Airline routes among European airports, where each of the 37 edge types represents **routes** by a different airline.
  - **Undirected, unweighted, multiplex network**.

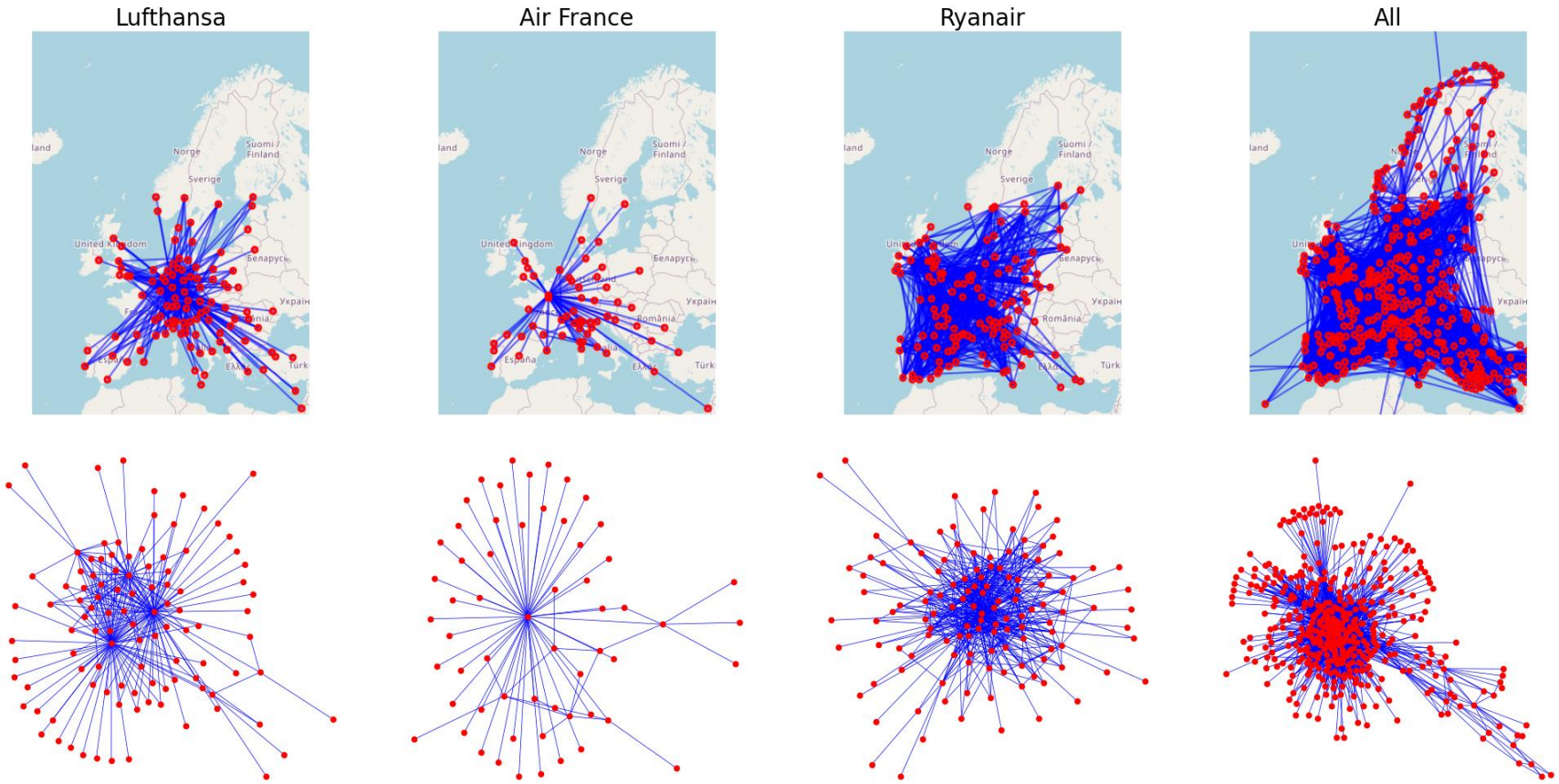
1 Network Description

- **Data Selection:**
  - **Lufthansa:** traditional, hub-and-spoke airline.
  - **Air France:** traditional, hub-and-spoke airline.
  - **Ryanair:** low-cost, point-to-point airline.

    ✚
  - **Whole European Network**: collapse of all airlines network.

1 Network Description

- **Data Selection:**
  - **Lufthansa:** hub-and-spoke.
  - **Air France:** hub-and-spoke.
  - **Ryanair:** point-to-point.
  - **Whole European Network**.



In the plots, we can already see some interesting insights...

→ **Goal**: confirm them quantitatively

2 Mesoscale Analysis: Communities

We have computed node communities for each of the networks using the following algorithms:

- **Greedy Modularity Maximization.**
- **Louvain Algorithm.**
- **Girvan-Newman Algorithm.**
  - Keep computing communities until a maximum of 15 is reached

3 Dynamic Analysis: Random Walks

We have simulated **random walks** on the network (1000 walkers, 10000 steps) and studied:

- Number of transits in each node.
- Number of walkers at the end of the simulation in each node

+

- Correlation of the previous parameters with centrality measures.

3 Dynamic Analysis: Synchronization

Synchronization

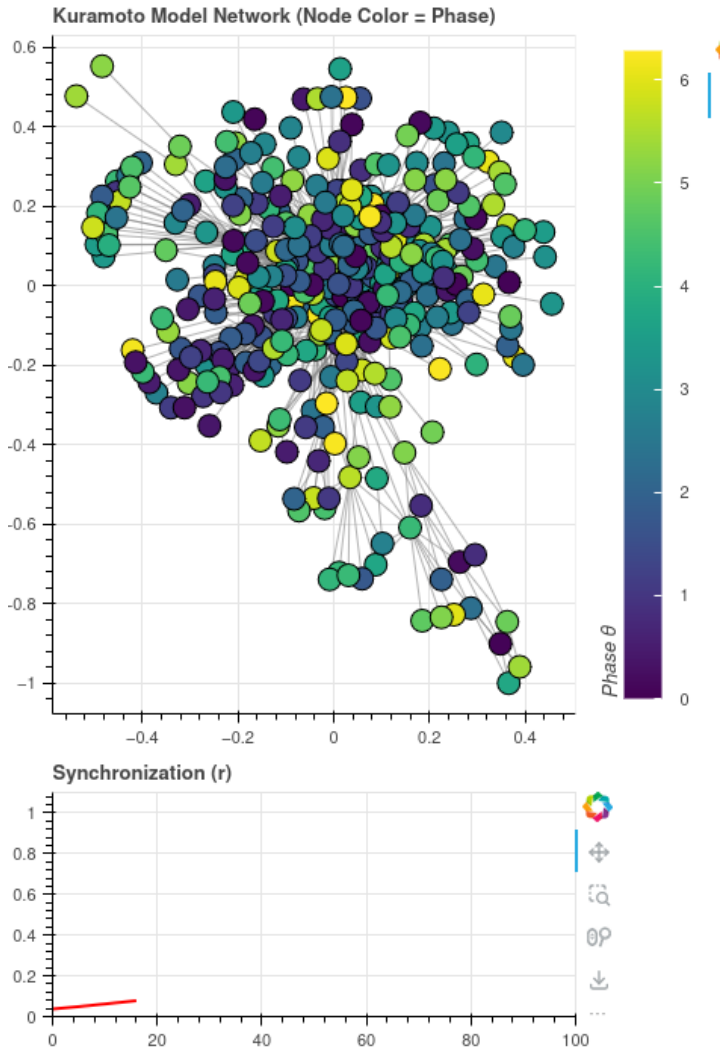
Setting the scenario:

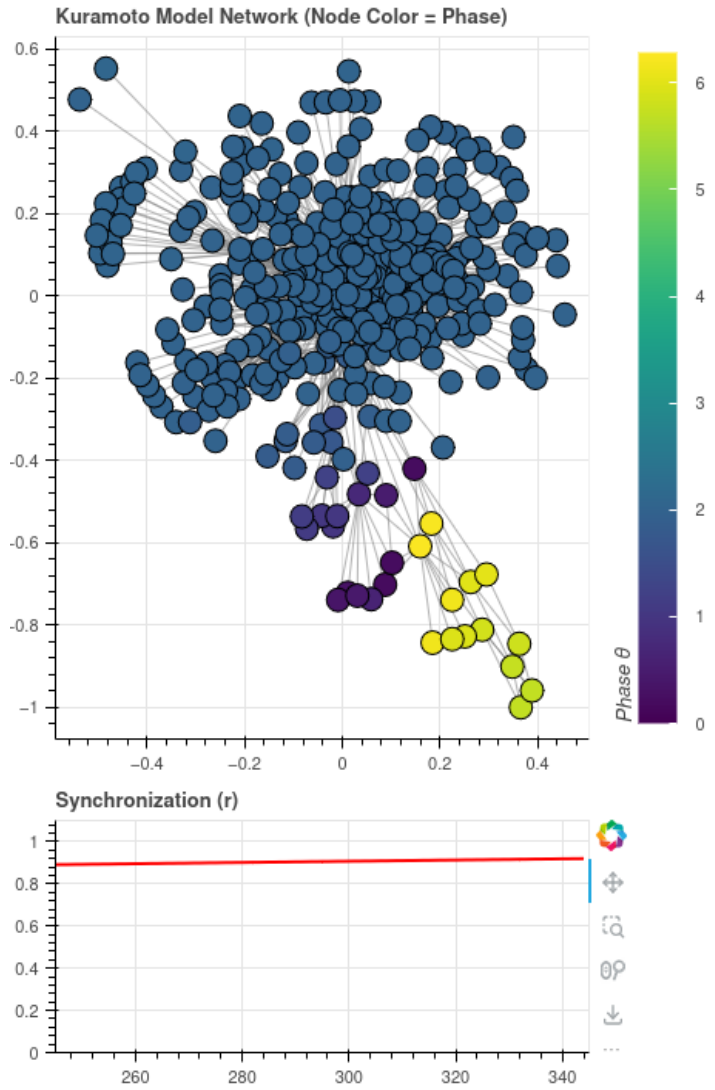
- Airports need to exchange information by opening a channel.
- They open it at every hour and can freely choose when (within such hour).
- The hour position is the phase.
- They have no internal tendency to change their phase. Their natural frequency is ω = 0.
- They can't reach a straight global agreement.
- They update their phase by looking at their difference with their neighbors. Not just this but following a Kuramoto model.

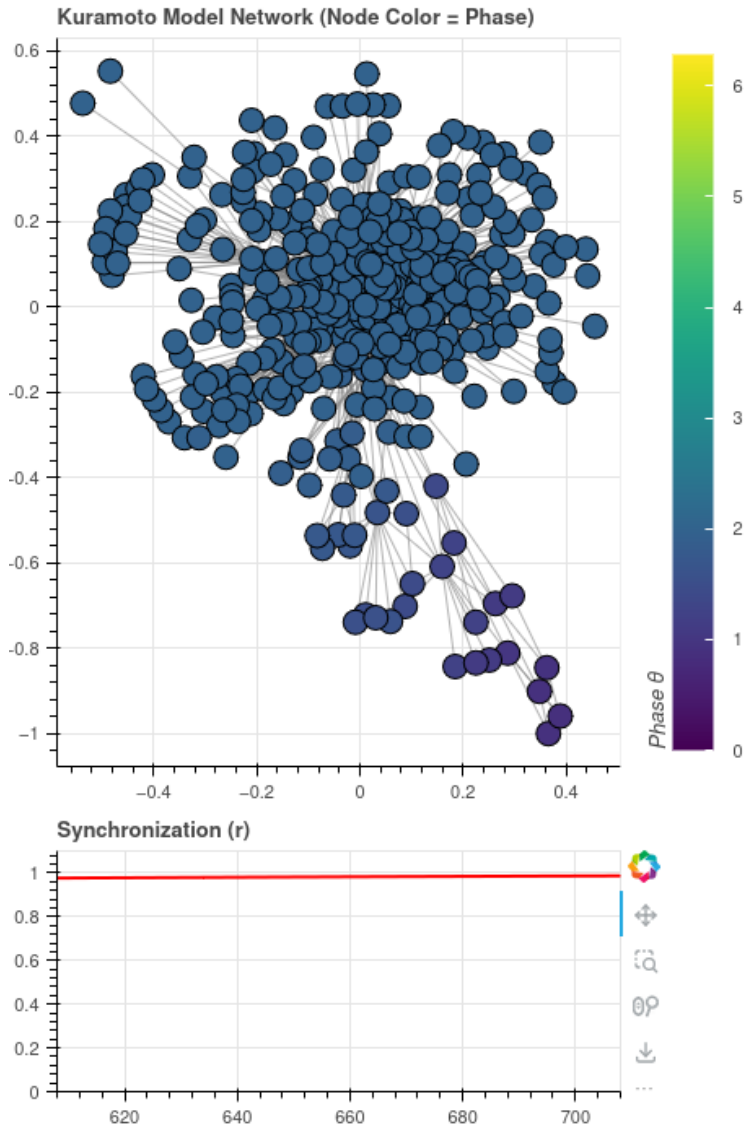
$$\dot{\theta}_i = K \sum_{j=1}^{N} A_{i,j} \sin(\theta_j - \theta_i)$$

Let's go to the notebook and see some results!

3 Dynamic Analysis: Synchronization







4 A network of networks

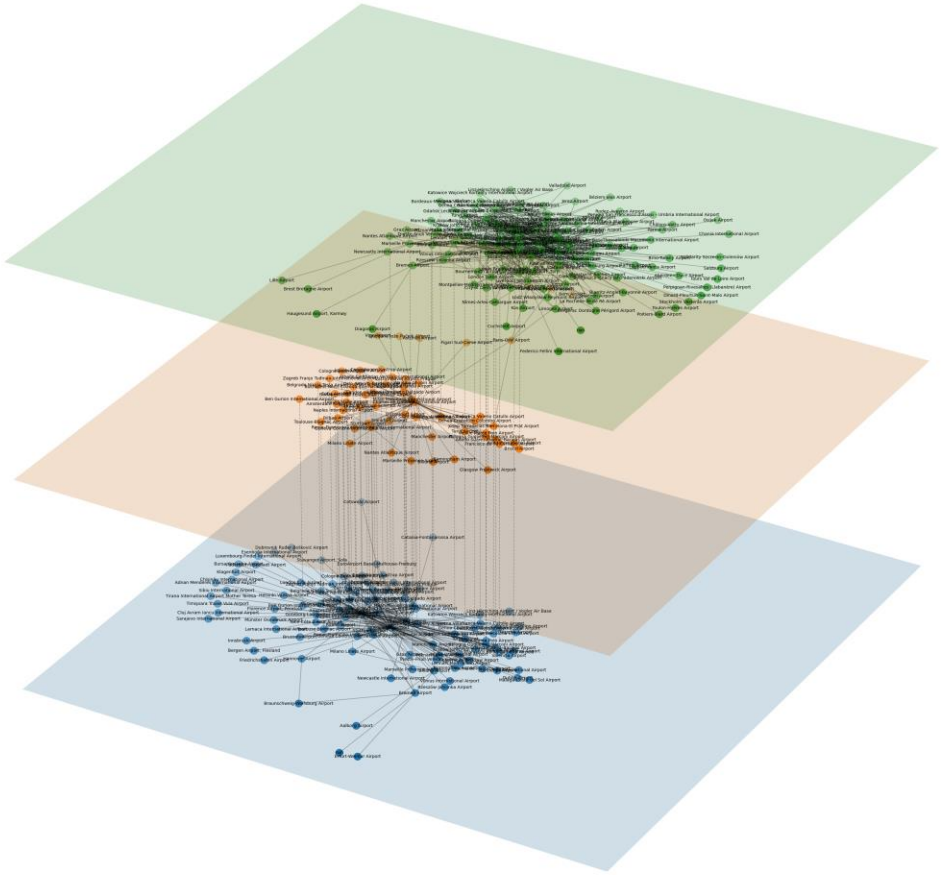
Multilayer network

- The airlines network naturally follows a multilayer structure.
- Each layer is an airlines network.
- The layers can be connected by connecting the nodes corresponding to the same cities.
- This visualization can be useful to:
  - See which cities are operated by both companies.
  - See which paths can you take to travel from a city operated only by airline A to one operated only by airline B (if you want to avoid the hubs).

4 A network of networks

Multilayer network

- The visualization is visually appealing.
- With so many nodes, it is difficult to interpret.



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Task 1

Microscale and Macroscale Analysis

Thanks for your Attention!

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Any questions?