Would humanity survive a Spanish flu pandemic today?

NTDS project

EPFL

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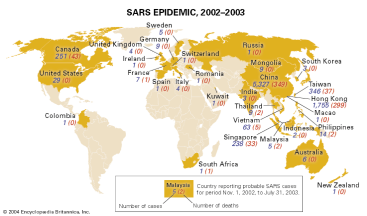
Overview

Introduction

Human existence has always been affected by diseases. As the world is more and more connected, the spread of a pandemic can be extremely quick and hard to track. We want to explore how a new illness could spread through the world and what control strategies could be implemented.

Spanish Flu

SARS epidemic



Dataset

OpenFlights/Airline Route Mapper Database

- 4 different datasets. (Airports, airlines, routes and planes)
- 7000+ airports initially, 3000+ after filtering
- 67000+ routes, a lot of routes repeated.
- Graph constructed using airports as nodes and routes as edges
- 11 connected in components resulting graph, 1 giant component.
- Graph follows a power law

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Airports network properties

- Only the largest component of the network is kept
- Only the *undirected* network is considered
- We refer to this network as the *airports network*

Properties of the airports network

Feature	**Value**
number of nodes	3186
number of edges	18832
average node degree $\langle k \rangle$	11.8
average squared node degree $\langle k^2 \rangle$	763.7
median node degree	4
average shortest path	3.958
diameter	12

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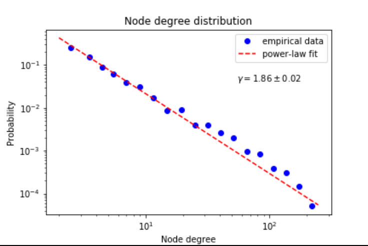
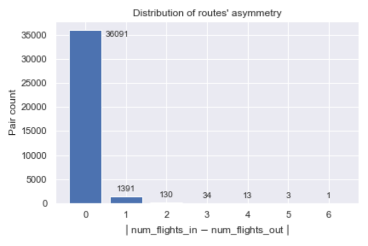
Airports network properties

Degree distribution



Routes' asymmetry distribution



- The network is scale-free with $\gamma = 1.86 \pm 0.02$
- 95.8% of the routes are symmetric

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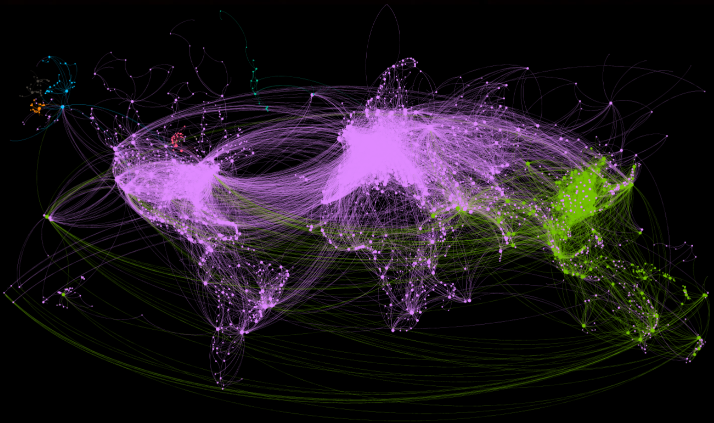
Spectral Clustering (SC)

- Clusters are based on graph properties
- One cluster contains the majority of the airports for any value of k



Dataset visualization performed by Spectral Clustering with 8 clusters

KMeans Clustering (KM)

- Clusters are based on latitude and longitude
- Clusters sized are balanced

Dataset visualization performed by KMeans Clustering with 8 clusters

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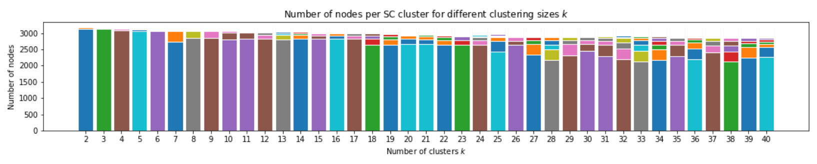
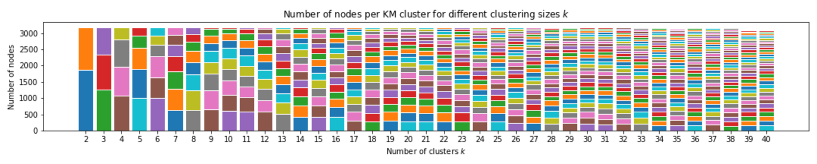
SC and KM Clusters Size Comparison

Spectral clustering



KMeans clustering



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Epidemics Model

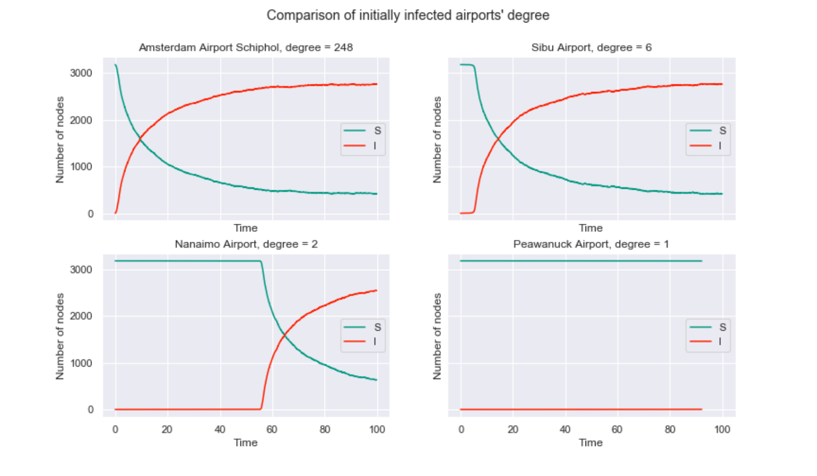
We use the *SIS* epidemics model

$$S \underset{\mu}{\overset{\beta}{\rightleftarrows}} I$$

We set the parameters β and μ in accordance with the Spanish-flu $R_0 = \frac{\beta}{\mu} = 2.5$
Model's interpretation:

- A susceptible airport i can be infected by an infected airport j with probability $\beta w_{i,j}$
- An infected airport can become susceptible at a rate μ

Spread Depends on Degree of Initially Infected Airport



Spread Depends on Degree of Initially Infected Airport

Endemic state reached: 87% of airports are infected

Control Strategies

1. `random_airports_removal`
   Shutdown of 20% of airports of the network. Airports are randomly chosen.
2. `random_neighbors_removal`
   Select 20% of airports at random, then shutdown a random neighbor for each of these.
3. `largest_airports_removal`
   Shutdown the top 20% connected airports.
4. `largest_routes_removal`
   Remove the top 45% connected routes.

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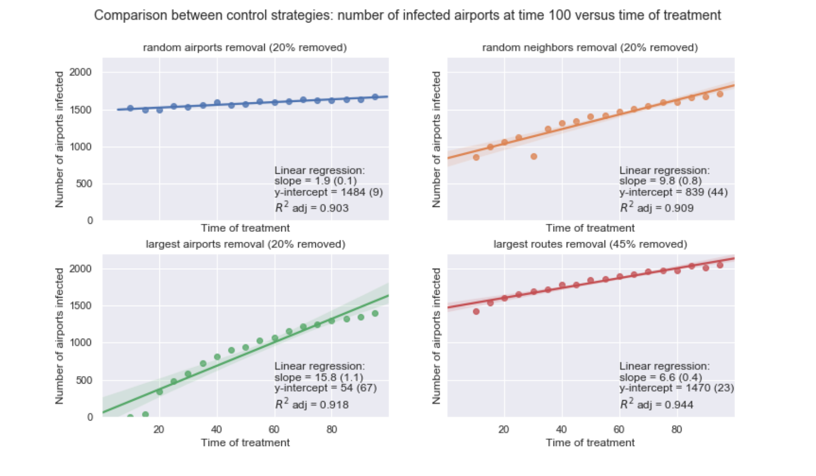
Control Strategies Comparison: Time of Treatment



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Control Strategies Comparison: Time of Treatment

- Random airports removal is quite ineffective (large y-intercept) and is not sensitive to the time of treatment either (small slope)
- Random neighbors removal is more effective (y-intercept = 839 vs 1484), and quite sensitive (slopte = 9.8)
- Remove largest airports is best: acting early completely disrupts the epidemics. It is the most sensitive too
- Remove (45% of) routes is not very effective. It is more sensitive than random airports removal

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Summary

- Most of the world's airports would be contaminated (87%)
- Remove most connected airports is the most effective strategy, it can disrupt the pandemics if applied early enough
- If a large fraction of the world's population succumbs, it is hard to predict whether humanity would survive

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Epidemics Simulation Example

Play epidemics spread animation if time allows!