Robustness study of Airline Routes Networks

Project Proposal

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CCS CONCEPTS

• **Networks** → Network quality / robustness

KEYWORDS

Robustness, Networks, Airline routes

1 MOTIVATION AND PROBLEM DEFINITION

Since last decade and the expansion of low cost airline companies, the number of daily flights exploded. Airplanes became a common way of travelling and represent now a real challenge. Thus, it is essential to assess the quality of the airline traffic and understand its weaknesses in order to prevent the risks and encourage its expansion.

Given an airline routes dataset, we will compare different network models in order to understand which one fits the best. We will also compute different robustness to measure the quality of the air routes networks.

Our work will focus on two main risks: natural disasters and isolated freezing (airport freezing after a snow storm for example).

A natural disaster is an incident that should be taken very seriously. For example, the Eyjafjöll volcano eruption in Island stopped the airline traffic all over Europe for weeks in 2010 with 100,000 flights cancelled, leaving more than 10 million passengers on the ground. It also generated a loss of $3 bn for the airline companies. We will model these disasters by removing several neighbor nodes in our network and analyze what happens next. We will also try to go further and by suggesting alternative representations for our network.

On the other hand, isolated freezing are frequent issues in the airplane traffic. They can be caused by a snow storm, a terrorist act or a power cut for example. They represent a real challenge, especially when it occurs in a hub. We will model this incident by removing a single node in our network and then proceed as previously.

2 METHODOLOGY

In order to achieve the goal fixed in the previous part, we suggest a three steps approach. First, we will focus on the modelling of the routes, comparing and evaluating different techniques. Then, we will study in detail the two risks (natural disasters and isolated freezing) impact on our network. Finally, we will try to suggest a better way to manage the current network.

2.1 Modelling of the airline routes and global study

To begin with, we will study the air transport network and its different characteristics. As air traffic network certainly contains some hubs with very high degrees, we will expect that it is a scale-free network and identify the power law of its degree distribution. In this case, the degree of an airport (node) is the number of airports that it is directly connected to by nonstop flights. The average path length, diameter and clustering coefficient will also give more insights about this particular network, as we believe that the air transportation network will let appear the small world phenomenon.

In addition, we will study the "betweenness centrality" of the network to determine if the most connected airports (in terms of degree) are also the most central (in terms of betweenness centrality). This will lead us to studying the community structure of the air transport network in order to understand the latter better. Being a scale free network, we will confirm that it is resilient to failures (nodes removed randomly) but vulnerable to targeted attacks to high-degree nodes.

In each part, we are going to use a random model as a baseline model. It will allow us to compare the features and metrics of our network.

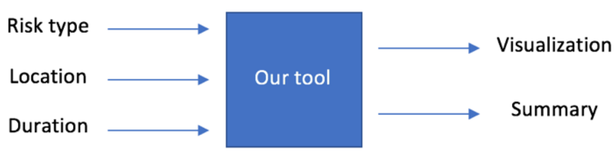
Moreover, we need to consider the spatial dimension in our work. In fact, it is essential because we want to simulate some actions with geographical impact (a natural disaster will affect the neighboring airports). We will thus visualize our data on a real map according the nodes (airports) locations.

Also, at some point, we may want to mathematically model it. The Barabasi-Albert model that uses the preferential attachment mechanism to generate an approximately scale-free model, or the fitness model, could be quality models for our purpose.

2.2 A tool to measure the risks impact

Here, we will build a tool that will let us measure the impact of the two risks on the airline network.

One will be able to simulate a risk and understand what happens. Our tool will receive 3 inputs: the type of the risk (natural disaster or isolated freezing), the location (of the volcano or the freezed airport) and the duration of the episode. It will then return a visualization of the situation and a summary. The visualization consists in a plot of the graphs before and after the event by highlighting in red all the impacted routes and airports. The summary is a list of metrics that will let us quantify the impact. It will be detailed in the Evaluation part. The schema below summarizes our tool:



2.3 An alternative solution (to go further)

This part can be likened to a research problem. Given the output of the previous part, we will try to understand what is the problem and then test different solutions to improve the previous model. It is difficult to describe in advance what we will do because it really depends on the outputs.

On the business side, we can see two relevant applications to this part. It could be a suggestion to change the network from now and suffer less in a risk situation. Nevertheless, this seems to be too optimistic. We more think that our solution can be used as an emergency plan in a risk situation.

3 EVALUATION

We will use for this work the Stanford openflight data set. It contains the air traffic routes given an airport id or an airplane id, a time span as well as the spatial coordinates of the airport comprised in both latitude and longitude.

We will narrow our work on the US network. It will be simpler to visualize and large enough to be consistent. We will then extract the data for a whole week, making the hypothesis that the information duplicates in that period, it will give an exhaustive representation of the network.

Furthermore, we will run sanity checks on our networks to see if the different values are coherent with the observed values in order to prove the usability of our models.

To evaluate the different models, we will compute different metrics that we will gather in the summary part of our tool. Let's give a first list that might be extended. First, we will measure the robustness as well as the mean and standard deviations in regard of the shortest flight path and compare these values between models. We will also give some business insights such as the number of missed flights, number of impacted passengers or the loss in $.

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