Studying delays propagations in aeronautical networks through PageRank

Massimiliano Zanin, Miguel Cea and Samuel Cristóbal
Innaxis Foundation & Research Institute
Velázquez 157, 28002 Madrid

As long as transportation networks - be them physical or informational - are becoming an essential part of our societies, the study of the behavior of such systems is attracting more and more interest, with the aim of finding more efficient and secure operations. A clear example is the air transportation network, for which the European Union forecasts a growth of a 220% before year 2030[1]. In this contribution we analyze how a specific kind of delay propagates through the network, i.e. the *reactionary delays*: that is when a flight arrives late at the destination airport, and that delay is propagated to the following flight, due to the limited time available on the ground to execute the required operations.

For that purpose we are going to use a modified version of the well known PageRank algorithm[2]. Initially developed to calculate the importance of web pages in a search engine, it has demonstrate its usefulness in different applications[3,4]. This algorithm is constructed upon agents, which at each iteration move to a node connected with the actual one (a neighbor) with a probability defined as a function of the weight structure of the network; with a certain fixed probability, they can also be moved to a new random node. The number of time a node is visited by an agent is proportional to its significance in the network (i.e. its centrality), and can be obtained by mean of the following equation:

$$PR_i = \frac{d}{N} + (1-d) \sum_t \frac{PR_t}{k_t} \tag{1}$$

where PR_i is the centrality of node i (or its PageRank number), d is the probability to place the agent in a new random node, N is the number of nodes in the network, and k_t is the degree of node t.

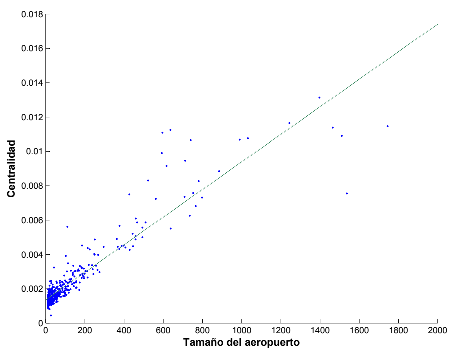

FIG. 1. Centrality values for the 464 European airports, as a function of its size (number of daily operations).

In our application, the parameter d has been tuned to obtain movement sequences with a mean length of 4 flights: we estimate this value by studying the real operation of airlines, obtained via airport web pages.

We consider that an airport B is sensitive to another airport A proportionally to the number of agents covering the route $A \rightarrow B$: that sensitivity is in turn representative of the probability of reactionary delays propagation. Using real traffic data of the 464 main commercial European airports we have obtained the results of Fig. 1 and 2. Clearly the biggest airports are the most critical part of the system: nevertheless, it is interesting to note as also many medium-sized airports contribute to the dynamics of the network, and therefore in the dynamics of delays propagation.

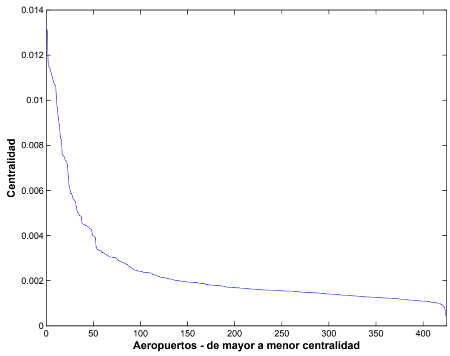

FIG. 2. Centrality of airports, in a descending order.

This kind of information is of utmost importance for strategic decision taking, as it allows a more rational resources allocation to certain nodes of the system that are acting as bottle necks. At the same time, this is an interesting example of interdisciplinary research, where a physical / mathematical algorithm is applied to a real system, with the aim to improve its efficiency.

* mzanin@innaxis.org

[1] STATFOR, the EUROCONTROL Statistics and Forecast Service, *Flight Movements 2008 - 2030* (2008).
[2] S. Brin and L. Page, The anatomy of a large-scale hypertextual web search engine, *Computer Networks and ISDN Systems*, **30**, 107 (1998).
[3] P. Chen, H. Xie, S. Maslov and S. Redner, Finding Scientific Gems with Google's PageRank algorithm, *Journal of Informetrics*, **1**, 1 (2007).
[4] N. Perra, V. Zlatic, A. Chessa, C. Conti, D. Donato and G. Caldarelli, Schroedinger-like PageRank equation and localization in the WWW, *arXiv*, 0807.4325 (2008).