Air traffic flow dynamics under the lens of ordinal patterns statistics

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As true for all socio-technical systems, one key ingredient to allow an effective and efficient management of air transport is to be able to access precise, and possibly real-time information about its dynamics. It thus comes as no surprise that benchmarking airport operations is not a new topic, and many research works have appeared in the last twenty years proposing different solutions [1]. Creating and evaluating a set of measures representing airport performance is of utmost importance for multiple stakeholders, from regulatory bodies to passengers and airlines, as it allows evaluating and selecting alternative investment strategies, and monitoring aspects like the evolution of safety or environmental impact. Additionally, a well-designed benchmarking metric in principle allows to compare heterogeneous airports, e.g. independently on the available infrastructure or traffic volume. On the other hand, this task is far from trivial, as many factors may hinder the results: from how measured variables are defined, to the underlying assumptions or the methodology employed in the analysis. Consequently, no single golden solution has been proposed yet.

We here propose the use of the permutation Jensen-Shannon distance (JSD), a symbolic tool able to quantify the degree of similarity between two arbitrary time series [2]. This quantifier results from the fusion of two concepts, the Jensen-Shannon divergence and the encoding scheme based on the sequential ordering of the elements in the data series [3]. More specifically, it constitutes a measure of distinguishability between two probability distributions, the symbol composition between different sequences can be quantitatively compared through this metric.

Our goal is to measure the presence of interactions between landing flights from a macro-scale perspective. We firstly present a synthetic model of landings at an airport, showing how the JSD is able to detect interactions arising from high volumes of traffic. Secondly, we show that air trafic flow volume can be considered as a modulated noisy signal, from which the high-frequency component is an auto-regressive process of first order AR(1). Real landing data for eleven major European airports are then analysed prevouis to the COVID19 pandemic, showing that the correlation parameter of the high-frequency component is proportional to the average landing separation—see Fig. 1. Moreover, we found that restrictions impossed after March 2020 reduced the temporal correlations in the traffic flow volume, as depicted in Fig.2 for Barajas airport.

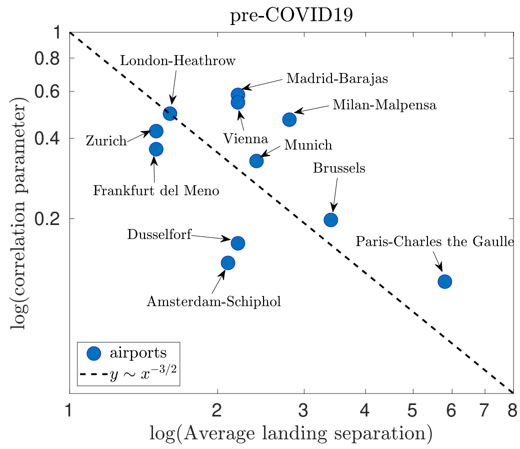

Fig. 1. Correlation parameter versus average landing separation in log-log scale for eleven major European airports pre COVID19 pandemic.

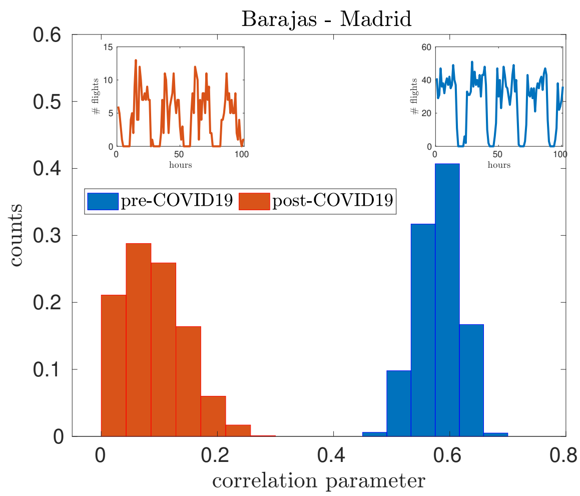

Fig. 2. Histograms of the correlation parameter pre and post COVID19 pandemic for Barajas airport. Inset left and rigth panels correspond to 4 days of operations after and before restrictions, respectively.

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