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Multiple airport regions based on inter-airport temporal distances

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ABSTRACT

We formulate and implement a new metric for identifying multiple airport regions (MARs) around the world, based on the temporal distance between airports. This metric, opposed to existing studies based on spatial distance, takes into account the real travel time between airports of latent passengers and their journeys via ground transportation. We investigate a variety of properties of the newly built MARs network at the global scale for the year 2015, including the importance of MARs in global air transportation, similarity clustering, destination overlap, and airport roles inside a MAR. Commonalities and differences to the simplified spatial distance are identified.

1. Introduction

Global air transportation faces tremendous demands and challenges (Balakrishnan et al., 2016; Cook et al., 2015; Wandelt and Sun, 2015). Meeting these high demands is critical, since current air transportation already suffers from significant congestion and delays (Belkoura et al., 2016), as well as hard criticisms on its negative environmental impacts (Wolfe et al., 2014), especially noise and emission in the vicinity of airports (Forsyth, 2007). Capacity at many airports is limited relative to current or projected passenger demands (Fernandes and Pacheco, 2002). Recent studies have increasingly used complex network techniques (Cook et al., 2015) to understand the processes of delay generation (Belkoura et al., 2016), delay propagation (Zanin, 2015), loss-of-separation (Zanin, 2014), and resilience (Sun et al., 2017). In such studies, analyzing the roles and functions of a single airport often provides a limited view on the real geography of air transport in general, especially in metropolitan areas where more than one airport serve the passengers with increasing long-distance mobility demand in a region (O'Connor and Fuellhart, 2016). Therefore, it is believed that the concept of Multiple Airport Regions (MARs) is an effective starting point for air transport research. The concept of MARs has emerged in the 1990s: It was defined as a group of two or more major commercial airports in a metropolitan region (de Neufville, 1986), and typically a major commercial airport was defined as an airport with at least two million passengers per annum.

One of the biggest challenges is to implement the operational interactions between airports in a MAR (Bonnefoy, 2008). Several researchers have addressed aspects of this problem, such as manage traffic allocation problems in a MAR (Hansen and Du, 1993) and the prioritization of arrival and departure routes in the terminal maneuvering areas of a MAR (Sidiropoulos et al., 2015). The MARs in existing large-scale studies often were defined by a spatial distance metric to estimate the airport catchment area, ranging from 50 km to 250 km: Airports within a fixed radius are aggregated as a MAR,

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starting with airports that have the highest numbers of passengers (O'Connor and Fuellhart, 2016; de Neufville, 1986; Bonnefoy, 2008; Hansen and Du, 1993; Sidiropoulos et al., 2015). However, there is an obvious caveat when using a spatial distance metric to define a MAR: Using the spatial distance assumes a homogeneous travel time from an airport to all concentric points at a given distance threshold. This view neglects the real infrastructure available for transportation and it is unlikely to capture the preferences and travel behaviors of passengers with a spatial distance based MARs (O'Connor and Fuellhart, 2016; Wittman, 2014). The reason for this simplification of distance is rather intriguing: When analyzing a large-scale network, it is difficult to obtain infrastructure data and service data for all regions. In fact, collecting infrastructure data for a single airport is often time consuming (Yang et al., 2016).

In this study we define the accessibility of an airport within a region based on a new metric: Temporal distance. This metric estimates how long it takes to travel between two airports, using either road network (by driving cars or taking taxis) or public transport (bus, lightrail, railway, subway, and tram). Our routing algorithms for finding travel itineraries between airports are based on the freely available data provided by OpenStreetMap (OSM), which has become an impressive source of worldwide public transportation and road network data, at a very high level of coverage (Neis and Zielstra, 2014). To compare the differences between spatial and temporal distance, we report the results of an initial experiment first. Fig. 1 presents the scatter plot between spatial distances using the haversine formula and temporal distances with our methodology for selected airport pairs. The haversine formula calculates great-circle distances between two points on a sphere from their longitudes and latitudes; while our methodology calculates the minimum travel time between two points by using either road network or public transport. Results are only shown for airport pairs with spatial distances less than 400 km and with temporal distances less than 4 h. Moreover, on the right-hand side of Fig. 1 we show a histogram of the travel speed between airports. There is no functional dependency and limited correlation between spatial distance and travel time between airports, which means that no fixed spatial distance can cover the real connectivity between different airports correctly. This is the major motivation for our study, analyzing the worldwide MAR network by using the temporal distance as a metric.

This paper is organized as follows. Section 2 provides the literature review on the state-of-the-art MARs analysis. Section 3 presents our methodology to construct MARs based on temporal distances, traveling either with road network or public transport. In Section 4, we present the results of worldwide temporal MARs. Finally, conclusions are drawn in Section 5.

2. Literature review

This section provides the literature review on the state-of-the-art analysis on MARs. Several researchers have studied MARs since the 1990s. A MAR was originally defined as a group of two or more major commercial airports in a metropolitan region (de Neufville, 1986). An inter-airport distance threshold of 50 km has been used for the definition of a MAR (Hansen and Weidner, 1995), a second criterion is that the Herfindahl concentration index for the airports in the region, which measures the degree to which passenger activity is concentrated is less than 0.95. The effects of improvements to airport ground access by non-automobile modes in a MAR were analyzed, with a case study of an extension of a Bay Area Rapid Transit rail

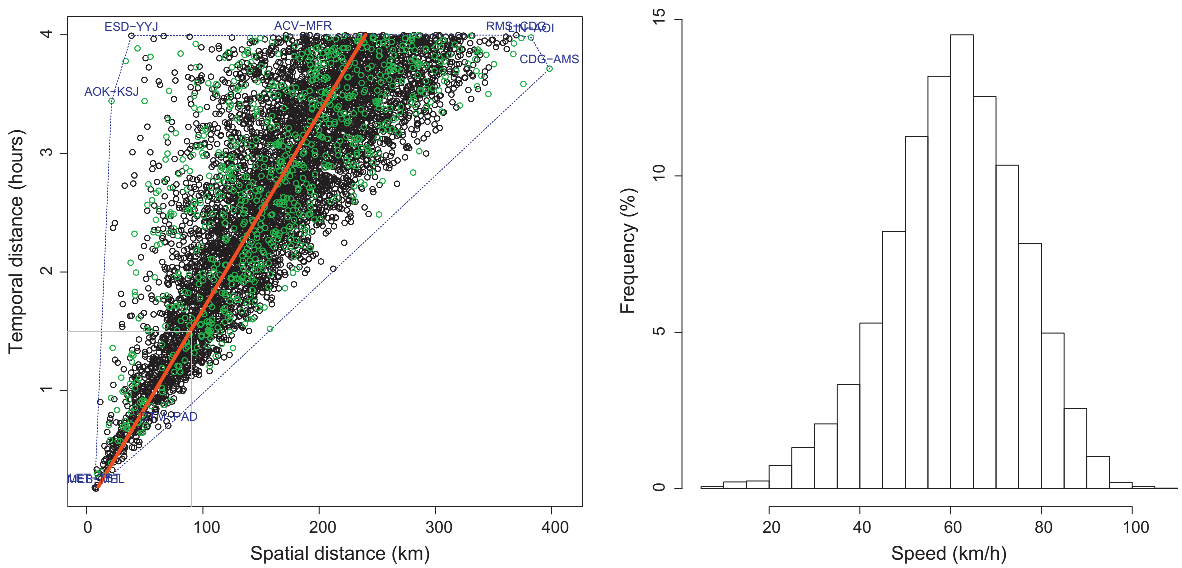

Fig. 1. Left: Scatter plot between spatial distances using Haversine formula and temporal distances with our methodology for selected airport pairs. Each circle represents one airport pair; circles shown in green colors are the airport pairs with direct flight connections, the blue dashed line represents the convex hull, the red diagonal line shows the travel time when the travel speed is 60 km/h. Right: Frequency distribution of travel speeds between airport pairs. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)