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An evolving model for the lodging-service network in a tourism destination

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HIGHLIGHTS

- A growing model that represents the lodging-service network is presented.
- The analytical degree distribution of services agree with numerical simulations.
- Model predictions agree with user-generated data from a tourism destination.
- The influence of X-motifs on the one-mode degree distribution is analyzed.

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ABSTRACT

Tourism is a complex dynamic system including multiple actors which are related each other composing an evolving social network. This paper presents a growing model that explains how part of the supply components in a tourism system forms a social network. Specifically, the lodgings and services in a destination are the network nodes and a link between them appears if a representative tourist hosted in the lodging visits/consumes the service during his/her stay. The specific link between both categories are determined by a random and preferential attachment rule. The analytic results show that the long-term degree distribution of services follows a shifted power-law distribution. The numerical simulations show slight disagreements with the theoretical results in the case of the one-mode degree distribution of services, due to the low order of convergence to zero of X-motifs. The model predictions are compared with real data coming from a popular tourist destination in Gran Canaria, Spain, showing a good agreement between analytical and empirical data for the degree distribution of services. The theoretical model was validated assuming four type of perturbations in the real data.

1. Introduction

In the last two decades, the complex networks perspective has been widely used to analyze diverse socioeconomic phenomena, such as professional collaborations [1–3], international trade networks [4–6], business networks [7–9] and also tourism [10–19]. The case of tourism is noteworthy. This is a geographical, economic and social phenomenon which consists on the temporary movement of some people (tourists) from origin countries to certain destinations, where they spend time

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enjoying some services (visiting natural or man-made monuments, restaurants, going shopping and other activities). The big amount of agents involved in this industry (visitors, lodgings, air carriers, local suppliers, services in destination, etc.) and the strong interdependence among them make this industry to be considered a complex adaptive system and susceptible to be analyzed using complex network methodology [20].

Nevertheless, the application of the complex networks approach on tourism research is still limited as compared to other fields. One of the reasons is the sample size, which is usually small in the real networks analyzed so far. This is due to the common methodology applied for the data collection, based on interviews of agents involved, which makes that obtaining samples larger than 10^2 nodes is monetary and time costly [10–13,16–18,21]. Regarding the issues explored, many of the previous contributions make statistical analyses to characterize the topological structure of a specific tourism network [13,15,16] or modularity analysis to detect communities [10,19,21]. Other papers go further and apply the superedges approach to tourism data [21], study the knowledge diffusion in the supply network [14], the influence of network topology on social capital of hotels [17] or the movement pattern of tourists in destinations [18].

Looking at the specific definition of the tourism network used, some of the contributions above study the supply-side network, where nodes contains stakeholders, such as hoteliers and travel agencies, which are linked through business associations or website links [10,14,16]. Other networks include locations who are linked by travelers [12,15]. Unlike to the rest, Smallwood et al. [18] analyze the tourist network combining the demand (tourist) and supply-side (activities/attractions).

To the extent of our knowledge, the application of complex networks to analyze the growth dynamic of the supply network in a tourism destination is still unexplored. However, this is a major issue in tourism research, since it would allow identifying the main forces leading to a destination from the initiating to mature stage and provide key factors about its next future evolution.

In this regard, the adaptation of evolving models of bipartite networks to the tourism context is an useful way to represent the phenomenon. Evolving models has been theorized for one-mode networks [22,23] and extensions to several cases of bipartite networks have been also proposed [24–30]. Following the same basis of one-mode evolving networks, these models assume that new nodes of both categories appear in every time step. The major difference among them is the specific combination of random and preferential attachment (PA) rules to link new and old nodes. For example, Ramasco et al. [24] assume new nodes are attached following an unidirectional combination of these rules (e.g., new movies select an amount of old and new actors), while Tian et al. [27] and Zhang et al. [28] assume bidirectional PA rule for selecting links between nodes from two categories, allowing rewiring which follows PA and/or random attachment rules. The latter models have been extended by Zhang et al. [29] including weight in the links. Alternatively, Noh et al. [25] create a growing model to represent the community growth through group membership, assuming that the join of a new member to an old group or creation of new groups is produced according old member's degree and random rules. Finally, Nacher et al. [26] adapt a bipartite growing network to represent protein-domain network including a copy mechanism and random rule for new nodes. As it was the case for one-mode distributions, the long-term degree distribution in the contributions above varies from shifted power-law to exponential distribution, depending on the specific weight of PA or random attachment rules.

This paper proposes an evolving model of bipartite network to represent the development and interrelationship of some components of the supply network in a tourism destination. In particular, the model explains how the lodgings and services in the destination grow and are connected each other through tourists' behavior. More specifically, a link appears if a representative tourist staying in a certain lodging enjoys a service. The behavior of this representative tourist is assumed prototypical of tourist preferences in the destination and therefore determines some of the components of the tourism supply. Thus, any service which is enjoyed by the representative tourist is considered in the model part of the tourism supply in the destination. The specific definition of the representative tourist depends on the characteristics of the real destination analyzed.

The propensity to enjoy a specific service follows a combination of preferential and random attachment rules. In the long term, services degree follows a shifted power-law or exponential distribution. The model estimations are tested with real data coming from a tourist area in Gran Canaria, Spain, collected from recommendations made by visitors in the booking web-site tripadvisor.com. The results show good agreement between theoretical, numerical and real data for the service degree distribution. The one-mode projection does not show so good fit results between numerical and theoretical data, due in part to the low order of convergence to the asymptotic state of the degree distribution. The theoretical model was compared with perturbations in empirical data and results show agreement between their degree distributions. Model limitations and future research are commented in the conclusions section.

2. The model

An evolving network is proposed to explain the supply growth in a certain destination. We assume two categories of nodes, lodgings (H) and services (S). Lodgings include the accommodation units in the destination, such as hotels, apartments, Bed&Breakfast, etc., and services include all the activities (visiting monuments, restaurants, etc.) that the tourist can make during the stay. The model shows how the links between elements of these categories appear along time until achieving an asymptotic network structure.

We start at time t_0 with an initial bipartite network, which is represented by a triple $G = (H_0, S_0, E_0)$, where H_0 and S_0 represents the initial lodgings and services in the destination, with $card(H_0) = H^0$ and $card(S_0) = S^0$. We assume $S^0 = mH^0$,