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Modeling and forecasting hotel room demand based on advance booking information

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HIGHLIGHTS

- Investigating key characteristics of hotel booking arrivals; time-varying arrival rates, high variability, and strong inter-temporal correlations.
- Examining stochastic models to capture essential features of booking arrivals.
- Suggesting a better forecasting method based on stochastic models of booking arrivals.
- Empirical study using real hotel reservation data for model validation.

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ABSTRACT

This study develops a stochastic approach to the short-term forecasting of hotel booking arrivals. We investigate the key characteristics of booking arrivals, specifically the time-varying arrivals rates, high variability in the final demand, and the strong positive correlations between arrivals in different time periods. We examine three Poisson mixture models to capture these salient features of booking arrivals. In particular, the presence of strong inter-temporal correlations can be leveraged for forecasting future arrivals based on the early realizations. We suggest a new forecasting method that exploits the intrinsic correlations between early and late bookings and then present validation results of data from a major hotel chain along with a comparison to benchmark models. Our empirical study confirms that our dynamic updating method leveraging inter-temporal correlations can significantly improve the short-term forecasting accuracy of hotel room demand.

1. Introduction

Demand forecasting is a crucial part of hotel revenue management that aims to maximize revenue by matching demand to available capacity. Previous studies such as those by Polt, 1998, Lee, 1990, and Chiang, Chen, & Xu, 2007, showed that for the airline business, a ten percent improvement in forecasting accuracy may contribute up to a three percent increase in revenue. Specifically, short-term demand forecasts of four weeks or less before the target stay day have a critical impact on hotel revenue management operations such as pricing decisions and inventory control. According to HotelNewsNow, 2012, the average hotel reservation lead time for North American travelers is 22 days. Our data report even shorter lead times: 50% of total reservations net of cancellations are made within ten days prior to the intended stay day, and 80% within 21 days.

In the short-term forecasting of hotel demand, among the most important types of data is advance booking information. Hotel customers may request reservations days, weeks, or even months prior to their intended stay day. Hotels maintain these reservation profiles for each calendar day, which is partial data until the stay night. Advance booking information, while incomplete, reflects the most recent demand shifts and seasonality differences (Zakhary, Gayar, & Atiya, 2008).

While hospitality industry heavily relies on booking information as accurate prognosticators of final demand, few efforts have been made to model booking processes beyond merely aggregating historical booking profiles. The goal of this research is to develop a stochastic model that predicts future booking arrivals based on advance booking information. More intensive research on stochastic models of arrival processes is done in the context of call centers. A natural approach to such time-varying arrival processes

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as call centers, hotels, and airline arrivals, is a non-homogeneous Poisson process (NHPP). In this paper, we examine NHPP variations (Poisson mixture models) proposed by Whitt, 1999, Jongbloed & Koole, 2001, and Avramidis, Deslauriers, & Lecuyer, 2004. Using stochastic models, we characterize hotel booking arrivals with a particular focus on strong inter-temporal correlation. Furthermore, we suggest a method which leverages the key properties of booking arrivals to improve the short-term forecasting accuracy of hotel room demand.

We provide both theoretical and empirical results of the proposed method. We examine how different Poisson mixture models can capture the salient characteristics of hotel arrivals. Then, using datasets from real-life hotels, we test different variations of the models that vary in terms of the complexity of the parameters and dimensions. We also compare the proposed method with popular alternatives such as regression.

Although the development of the model is motivated by a hotel application, our stochastic models of arrivals and forecasting method based on advance bookings may be applicable to many other tourism areas. Tourism products, such as unfilled airline seats, unoccupied hotel rooms, and unused facilities, cannot be stocked owing to their perishable nature (Archer, 1987; Pai & Hong, 2005). Accurate demand forecasting, usually measured by the number of arrivals, is essential in assisting in managerial, operational, and tactical decisions (Athiyaman & Robertson, 1992; Pai & Hong, 2005). Moreover, one of the most salient characteristics that differentiates tourism products from traditional purchase cycles is advance bookings. Advance booking information provides useful insights into demand prospects, as is carefully observed in most travel industries. Thus, forecasting models capturing the characteristics of advance bookings will be useful in other areas of the travel industry such as the airline, sports and concert ticketing, and events and conventions segments.

This paper is organized as follows. In section 2, we review the literature on hotel demand forecasting and NHPP models. In section 3, we describe hotel booking processes and examine the key characteristics of booking arrivals. Then, we present three stochastic models of booking arrivals. Section 4 is devoted to empirical results and an application to demand forecasting. Finally, section 5 contains our conclusions and a perspective on future extensions of this work.

2. Literature review

2.1. Hotel demand forecasting

While accurate forecasting of bookings is the key to the success of hotel revenue management, there have been only a few published papers on forecasting hotel booking arrivals. Many studies of hotel forecasting have their origins in airline revenue management. Lee, 1990; Weatherford & Kimes, 2003; Chen & Kachani, 2007 provided a good review of forecasting problems in airline and hotel revenue management. Hotel forecasting methods fall into one of three types: time-series models, advance booking models, and combined models.

Time-series models consider only the final number of rooms on a particular stay night (Zakhary et al., 2008). Simple time-series models such as exponential smoothing, moving averages, and regression as well as more advanced models such as ARIMA in various forms are used for forecasting based on historical daily final demand.

Advance bookings models consider arrivals of reservation requests over a booking horizon for a particular stay night. At any given time over a booking horizon, partial (already realized) demand is known. This early realization, while partial, reflects the most recent demand shifts for a particular stay night, and it is considered as the most accurate prognosticators of final demand in short-term forecasting. The main idea of advance booking models is to estimate the increments of bookings to come and then aggregate these increments into the early realizations to obtain a forecast of the final demand. Hence, advance booking models require the development of reservation profiles (booking curves), which estimate how bookings materialize over a booking horizon.

Advance booking models can be grouped into additive models and multiplicative models. Additive models assume that the number of reservations on hand on a particular day before arrival (or the reading day) is independent of the final number of rooms sold, while multiplicative models assume that the number of reservations yet to come is dependent on the current number of reservations on hand. Additive models add the current bookings on hand to the expected remaining bookings. On the other hand, multiplicative models assume that future bookings are proportional to current bookings; therefore, to determine the final forecast, current bookings are multiplied by the average booking rate (Zakhary et al., 2008).

Combined models use either regression or a weighted average of historical and advance booking models to obtain the final forecasts (Zakhary et al., 2008). Combined models are widely accepted in practice to increase the forecasting accuracy. Work by Rajopadhye, Ghalia, Wang, Baker, & Eister, 2001 is a good example of a combined model, which blends a time-series model (Holt-Winters method) and an advance booking model (multiplicative pickup method). However, this study demonstrated the proposed model on simulated arrivals without verification with actual hotel data.

Weatherford & Kimes, 2003 compared among several time-series models and advance booking models for daily hotel room forecasting. They showed that whereas the best forecasting method varies by property, rate category, and the length of stay, advance booking models and exponential smoothing produced overall low errors. While this is one of a few studies that tested and compared forecasting models on real hotel data, their study is limited to only simple forecasting methods. Chen & Kachani, 2007 also compared classic different hotel forecasting methods including simple time series, advance booking methods, and combined models. They computed different measures of accuracy as well as the revenue impact of forecasting methods.

Of particular interest to this study is advance booking methods. Zakhary et al., 2008 investigated specifically advance booking models in various forms and compare the forecasting results of several pickup models using simulated hotel reservation data. They found that multiplicative variations appear to outperform additive variations, though additive variations generally appeared to be more robust.

Of key importance with advance booking models is the manner in which future booking arrivals to come are estimated. Most previous research on advance booking models used empirical booking curves that are computed simply by averaging accumulated reservations in past data. There have been few analytical attempts to model the dynamics of future booking arrivals. Tse & Poon, 2015 attempted to describe the shape of the booking curve as a quadratic function. Zakhary, Atiya, El-Shishiny, & Gayar, 2011 suggested a probabilistic hotel arrival model based on Monte Carlo simulations. They modeled reservation and cancellation arrivals as a successive binomial process.

2.2. Nonhomogeneous poisson process (NHPP) and poisson mixture models

While there are only a few published studies of analytical models of hotel booking arrivals, more intensive research on stochastic models of arrivals has been done in the context of call centers. A natural model for time-varying arrivals, as is the case for