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An introduction to helpful forecasting methods for hotel revenue management

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ABSTRACT

Revenue management is a key tool for hotel managers' decision-making process. Cutting-edge revenue management systems have been developed to support managers' decisions and all have as an essential component an accurate forecasting module. This paper aims to introduce new time series forecasting models to be considered as a tool for forecasting daily hotel occupancies. These models were developed in a state space modelling framework which is capable of tackling seasonal complexities such as multiple seasonal periods and non-integer seasonality. An empirical study was carried out to illustrate how a practitioner may apply and compare the performance of different models when forecasting a hotel's daily occupancy. Results showed that the trigonometric model based on the new modelling framework generally outperformed the majority of the other models. These findings are potentially useful to the entire revenue management community facing the challenge of accurately forecasting a hotel's daily demand.

1. Introduction

The aim of this paper is to introduce a relatively new time series forecasting method as a tool to be considered for forecasting a hotel's daily demand with complex seasonal patterns. This paper starts with a description of the proposed forecasting methods, followed by a discussion of its theoretical promise for forecasting a hotel's daily occupancy. Finally, a demonstration is provided on how a practitioner (hotel manager, revenue manager, researcher, etc.) may apply and test those methods against traditional historical forecasting methods.

There is increasing interest in forecasting methods for hotel revenue management, because it has been recognised that timely and accurate hotel daily occupancy forecasts by market segments contribute to maximising revenues through demand-management decisions, such as pricing and inventory allocation (Talluri and van Ryzin, 2004). Some authors have stressed the importance of using forecasting in a revenue management system (e.g. Chiang et al., 2007; Talluri and van Ryzin, 2004; Hayes and Miller, 2011), while others have compared the performance of traditional methods for short-term hotel demand forecasting. Traditional forecasting methods include time series methods based on historical data, methods based on advanced booking data and combined methods (Weatherford and Kimes, 2003). Historical data typically comprise a set of past observations of the final demand (e.g. number of daily occupied rooms), while advanced booking data refer to all information about the accumulation of reservations for a given future date of stay (bookings-on-hand data).

The methods based on historical data, which can be found in numerous studies (e.g. Gardner, 2006; Talluri and van Ryzin, 2004; Weatherford and Kimes, 2003), include univariate time series models like moving average, exponential smoothing and other autoregressive methods (ARMA family models), as well as econometric regression models and other types of models (neural networks, principal component analysis).

The methods based on advanced booking data are mostly found in the revenue management literature (e.g. Schwartz and Hiemstra, 1997; Talluri and van Ryzin, 2004; Weatherford and Kimes, 2003; Chen and Kachani, 2007; Zakhary et al., 2011; Tse and Poon, 2015); however these are beyond the scope of this paper. Two reasons justify this exclusion. First, this paper aims to show new, possibly helpful forecasting methods based on historical data, namely with multiple seasonal periods and high frequency (daily data). Second, important research on methods based on advanced booking data have recently been published (Haensel and Koole, 2011).

The combined methods are typically based on a weighted average of forecasts obtained from different methods and different sources of information (see De Gooijer and Hyndman (2006) and

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Wong et al. (2007) for a good review of the literature on combination forecasts). There is empirical evidence from the general forecasting literature (e.g. see De Gooijer and Hyndman (2006) and the papers cited therein), that combining forecasts generated from different models can substantially improve forecasting accuracy compared to forecasts produced by a single forecasting model. For example, Rajopadhye et al. (2001) tested combined methods to forecast hotel demand. Other examples of combined forecasts in the field of revenue management are summarised in Weatherford and Kimes (2003). Thus, an improvement in the forecasting performance based on historical data may improve the quality of the combined hotel demand forecasts, helping revenue management forecast for the real world. However, combined forecasting methods are also not discussed here, although it is recognised in the forecasting-related literature that they are particularly useful to reduce errors of individual forecasts (Armstrong, 2001; Hibon and Evgeniou, 2005; Wong et al., 2007).

Before 2000, traditional forecasting methods dominated the hotel's demand forecasting literature, but this trend changed at the beginning of the millennium as some researchers tried to improve the accuracy of hotel daily occupancy forecasts by either using new approaches or studying the behaviour that influences the difference between hotel's demand and the real room occupation. Morales and Wang (2010) proposed a data mining method of forecasting cancellation rates using sources of internet-related data. In turn, Pan et al. (2012) used the same sources of data (search engine data) to forecast weekly room nights sold for a destination using time series and econometric models. Recently, Schwartz et al. (2016) proposed a recursive approach to improve the accuracy of hotel daily occupancy forecasts by including the prediction of the hotel's competitive set as an input in its own forecasts. All these approaches are very promising for the overall improvement of forecasts for daily hotel occupation, but they are also outside the scope of this paper. As in all fields of knowledge, this paper attempts to explore an alternative approach to achieve the same goal: to produce forecasts for daily hotel room demand with the best possible quality, which can be combined with other approaches in the future.

A key factor for the success of a revenue management system is to use high quality disaggregated forecasts for a long forecasting horizon (up to two months or so) (Weatherford and Kimes, 2003). For this reason, it is crucial that the selected time series forecasting method will be able to produce accurate forecasts for dates farther away (2–8 weeks), because it is expected that the pick-up methods will be very accurate for the short forecasting horizon (1–2 weeks). Given the importance of producing accurate forecasts for a long forecasting horizon, this paper illustrates the merits of the proposed time series methods when applied to real-life hotel disaggregated demand data for multiple step-ahead forecasting horizons up to eight weeks.

Regarding method comparisons, for example, Rajopadhye et al. (2001) studied the accuracy of a few forecasting methods using a set of hotel demand data. Weatherford and Kimes (2003) compared several traditional historical and advanced booking methods with hotel data. They applied moving average, simple exponential smoothing and regression methods to historical data and both additive and multiplicative pick-up methods to advanced booked data. Their results showed there was no single best method for all cases; rather it depended on the segment. However, the simple exponential smoothing method was identified as the best (with the lowest mean absolute error) for a majority of the time for a given segment, based on historical data. A few years later, Chen and Kachani (2007) concluded that simple exponential smoothing was the most accurate method using demand data from a well-known hotel. There are several other papers that deal with forecasting hotel demand or tourism demand (e.g. Andrew et al., 1990; Law, 2004; Yüksel, 2007; Song and Li, 2008; Lim et al., 2009), but characteristics of these time series are different from those forecasted here. Usually aggregated hotel or tourism demand time series (e.g. monthly, quarterly or annual occupancy rates, guests nights, tourist arrivals, etc.) do not exhibit high-frequency and complex seasonal patterns, which are the main time series features accommodated by the new models used in this paper.

Indeed, a literature review in the field of revenue management revealed extensive literature on key areas for revenue management (pricing, capacity control, overbooking), however, less was published on forecasting problems of short-term hotel demand data (Chiang et al., 2007; Chen and Kachani, 2007; Koupriouchina et al., 2014). In addition, research published so far on forecasting has not taken into account complex seasonal patterns that the majority of hotel daily demand time series exhibit. Several hotel short-term demand time series have double seasonal effects, while others may have patterns with a non-integer period. For example, it is frequent that a daily time series of hotel demand has a weekly seasonal pattern with a period of 7 and an annual seasonal pattern with a period of 365.25. Thus, traditional time series methods (simple exponential smoothing or simple SARIMA) are not completely suitable for forecasting complex seasonal and high-frequency time series because they were developed to model a single seasonal pattern with a small integer-valued period (such as 4 for quarterly data or 12 for monthly data).

Although there are methods for forecasting time series with complex seasonal patterns in the literature of statistics, as far as we know, none have been used in the field of hospitality management. Therefore, an added value of this paper is to provide hospitality management researchers, practitioners and solution providers with another kind of forecasting framework which might best suit time series patterns used in revenue management systems. Actually, De Livera et al. (2011) proposed a general framework to address the complexity of the seasonal pattern, which can now be easily implemented using the *forecast* package for R (Hyndman, 2015). Of course, there is no theoretical guarantee that the new forecasting models deducted under that framework will lead to improved accuracy of daily occupancy forecasts for short and long forecasting horizons. Therefore, another important contribution of this paper is the empirical study in which we demonstrate how to apply these models and compare their performance with the naïve method called 'same day of last year'.

This paper is organised as follows. Section 2 presents three time series models which address double or complex seasonal patterns in high-frequency time series. Several accuracy measures used to assess forecast quality are also outlined in this section. Section 3 describes the dataset used in the empirical study and discusses the results. Finally, some concluding remarks are presented in Section 4.

2. Methods

The widespread use of exponential smoothing methods in business and industry applications related to capacity control, pricing and trading, led us to consider the use of extended approaches of the standard Holt-Winters (HW) exponential smoothing formulation in the field of revenue management. The advantage of the exponential smoothing approach is its well established popularity in business forecasting and its relatively straightforward automatic implementation. In this section, we present and discuss three exponential smoothing models that may be useful to forecast hotel daily occupancy, y_t ($t = 1, \ldots, n$). Since no forecasting model is suitable for all applications, practitioners usually apply alternative forecasting models and conduct a forecast evaluation study to select the most accurate model. Thus, six forecast accuracy measures are reviewed at the end of this section.