Using multiplicative hybrid hedonic pricing model for improving revenue management in hotel business

Slava Kisilevich, Daniel Keim, Yossi Palivatkel and Lior Rokach

Abstract— In the age of Internet, online shopping attracts millions of customers worldwide. Since the same product can be purchased from different sellers, usually the price is a crucial factor in decision for buying a product from a particular retailer. This puts a lot of pressure for e-commerce companies struggling to preserve and maximize their revenues from Business-to-consumer (B2C) and Business-to-business (B2B) activities. In this paper, we describe a hedonic pricing model based on a multiplicative hybrid regression process for estimating hotel prices. The model is developed as a response to the need for better deal negotiation between product suppliers and retailers, hence, yielding better revenue management. In addition, we propose a spatial decision support system that can be used by domain experts to discover unprofitable deals.

Index Terms—Hotels, hedonic pricing model, regression, price estimation, geovisualization, decision support system

1 Introduction

The global nature of the Internet allows e-commerce companies to reach their customers without respect of their place of residence. At the same time, customers have wide options for selecting the best retailer to buy a product. It can happen that the price for the same product can differ from retailer to retailer and the customer will try to find the best offer that includes price among other factors. As a result, there is a constant competition between e-commerce companies to attract the customer and increase the revenue. One of the domains where the competition among retailers is extremely high is hospitality business, where prices usually fluctuate more frequently than in any other domains. Understanding the factors that effect hotel prices received much attention in the research (e.g. [5, 11, 9, 6, 2]) where different pricing models were proposed based on the hedonic pricing theory [10]. Various recommendations were proposed to hoteliers to improve price decisions and manage the revenue. However, the findings of current works can not be generalized since the results can be influenced by the empirical method and components selected for analysis or by local factors that do not exist in other geographical areas.

Another drawback of previous works is a complete automation of the algorithmic process, without a possibility for a domain expert to participate in the decision making. It is commonly agreed between experts in the hospitality domain that factors that influence hotel prices are comprised from attributes pertinent to a room in a hotel (e.g. hairdryer, safe), attributes that are pertinent to a hotel (e.g. parking lot) as well as attributes that are spatial in nature (e.g. hotel location, proximity to the center of the city). Besides the degree of data complexity and heterogeneity, usually, problems that include spatial elements are ill-defined [1] and cannot be completely processed without human support and background knowledge since improper resolution of the geographical extent may produce incorrect or unsatisfactory results [3].

The contribution of this research-in-progress work is twofold. First, we propose a new hedonic model for price estimation based on multiplicative hybrid regression analysis [4]. The estimated hotel price can be compared to the real hotel price and can be used as an indication of the departure of the proposed price from the real value of the hotel. Second, we propose the prototypical spatial decision support system that allows the domain expert to build models for a specific geographical area, to evaluate and judge the results using his/her domain expertise and knowledge. The spatial decision support system should be simple enough to let the domain expert easily perform the analysis and complete in terms of the tasks the domain expert should perform such as navigation, data selection, model creation, hotel selection, model application, refinement, geovisualization.

- *Slava Kisilevich and Daniel Keim are with University of Konstanz, E-mail: {slaks,keim}@dbvis.inf.uni-konstanz.de*
- *Yossi Palivatkel is with Travel Global Systems, E-mail: yossi@tgs-systems.com*
- *Lior Rokach is with Ben-Gurion University of the Negev, E-mail: liorrk@bgu.ac.il*

Manuscript received 31 March 2010; accepted 1 August 2010; posted online 24 October 2010; mailed on 16 October 2010.
For information on obtaining reprints of this article, please send email to: tvcg@computer.org.

2 Related Work

The research on hospitality industry has concentrated on analysis of factors that might enhance the strategic pricing and revenue management.

Future hotel room demand was modeled by a fuzzy rule-based approach in [5]. The hotel managers provided insights into the revenue management domain and their strategies for problem solving. The acquired knowledge-base was transformed into a set of fuzzy rules and an intelligent decision support system was developed.

Room rate characteristics for 74 hotels in and around Oslo were studied by [11] using log-linear regression. Such factors as availability of mini-bars and hairdryers in a room, and parking near the hotel significantly influenced the hotel price. However, room rates were lower in hotels that offer room service. In addition, hotels associated with chains are more expensive than non-chained hotels.

In the study about hotels in Taiwan [6], it was shown, by applying quantile regression analysis, that the age of hotels is negatively related to hotel price, while there is no significant difference between chained and non-chained hotels. Yet in another study that included 73 hotels in Taipei [2], was found that such factors as breakfast, business center or swimming pool do not influence the room price, while the hotel location, Tv, Internet access and availability of the fitness center have significant influence on room rates.

[8] showed that hotel prices are affected by proximity of a hotel to an airport or to central business districts.

[9] applied econometric modeling to estimate the "objective" economic value of different hotel characteristics such as proximity to the beach, distance to the downtown, neighborhood safeness, hotel class, customer reviews, etc. The econometric model predicts the actual price for a hotel and estimates its overall ranking (overpriced, underpriced) by calculating the difference between the averaged predicted price and the averaged real price.

3 Problem Domain

Travel Global Systems Inc. (TGS)[1] serves as a Travel Service Provider (TSP), and the hotel broker between Product Suppliers (PSs) and consumers. TGS provides solutions to travel agencies (B2B) as well as to individual consumers. Accordingly, various PSs offer TGS attractive room prices, which TGS is committed to promoting by means of its Web sites and services. The same PS can provide other travel groups that offer similar services like TGS a lower price for the same room. This situation can lead to considerable loss of revenue. However, searching for the prices of the rival companies is unfeasible due

[1] http://www.travelholdings.com/brands_tgs.html

to the high volatility of search space (the hotel prices differ daily, and there is a vast amount of PSs and TSPs). Therefore, the managers are interested in a decision support system that can identify hotels within TGS's own database that possess the same characteristics (price changes, closeness to the transportation or points of interest, amenities in the room, etc...) and predict the objective price of the hotel in question. The comparison of the offered and predicted prices can give TGS the "leverage" to negotiate the lower price with a product supplier.

4 METHOD

In this research we build a hedonic pricing model for each hotel and try to forecast its price in two weeks. We choose to analyze the time window of two weeks because usually most of the rooms are ordered in this window. In this paper we are employing a multiplicative hybrid model which includes the following three components:
(1) We estimate the base-price of a regular single-room in the targeted hotel using a regression tree. The regression tree is trained using the non-geographical attributes of the targeted hotel, such as: hotel class (star ratings), amenities, etc.
(2) The second component estimates the pricing multiplier of the target hotel compared to other hotels in the same area. The aim of this component is to take into account the dynamic nature of the pricing by assuming that nearby hotels exhibit similar pricing patterns. For example we can decide to increase the price of the targeted hotel when there is a rise in prices of nearby hotels. For this purpose we are using ridge linear regression.
(3) The third component is using geo information for obtaining the geo-multiplier. Specifically, we examine how the distance of the hotel to the various POIs located in the same city affect the price. For the third component we found that support vector machine for regression shows the best results.

5 SPATIAL DECISION SUPPORT FRAMEWORK

The main components of the decision support framework are presented on Figure 1 and consist of four main parts: the components labeled as (1) are the databases that store information about hotels (prices, amenities), points of interest and attractions (museums, theaters), business locations (restaurants, pubs), relevant transportation locations (underground metro, bus stations); the second component (labeled as 2) is responsible for the model generation of individual sources. For example, hotel properties can be summarized in a feature vector while clustering can be applied on business locations to find areas where there are a lot of restaurants. The third component (labeled as 3) is the data mining engine that builds a price estimation model using the individual models from the second component as an input. The hotel price spatial decision support system (labeled as 4) is a graphical user interface that the decision maker or a domain expert uses in order to see the results of the analysis and performs other relevant tasks such as navigation to the area of interest, hotel selection, model generation, geographical visualization. As was mentioned in Section 1, the model is comprised from very heterogeneous data (spatial, numerical, categorical) that require different approaches for visualization. The analyst should not only see the statistical properties of a hotel but also be able to locate it on the map to better understand the conditions of the area and retrieve other characteristics that may influence the hotel price such as points of interest as a preparatory step for model construction. Moreover, the domain expert should also review and refine the resulting spatial models. Therefore, the map navigation, data manipulation and geovisualization is an important component of the spatial decision support system. This is achieved by extending GEO-SPADE, a Google Earth-based framework [7].

6 CONCLUSION

The paper describes a research-in-progress work on hotel price estimation using multiplicative hybrid hedonic pricing model. The hybrid model is based on hedonic pricing theory and combines statistical

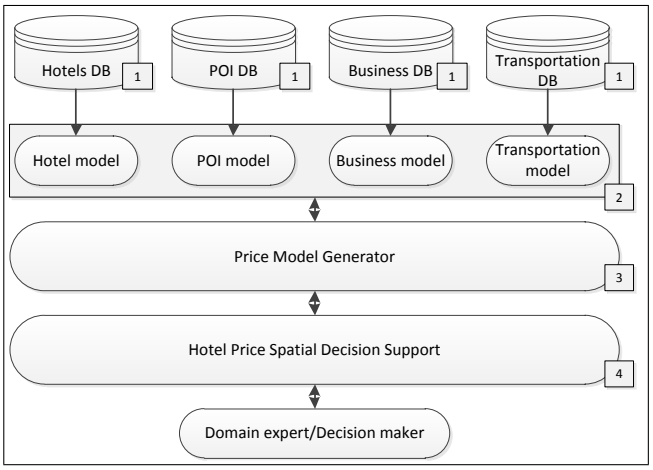

Fig. 1. Spatial decision support framework for hotel price estimation

methods with methods that originate from the field of data mining and machine learning. Most of the existing approaches on price analysis in hospitality domain concentrate on finding factors that affect the price. These findings serve as a possible recommendation for hoteliers to improve the services or adjusting prices. However, no work to the best of our knowledge, proposes a spatial decision support tool to facilitate the analysis of hotel prices. This work closes the gap between the power of computational algorithms and the human ability to drive the analysis and evaluate the produced results.

ACKNOWLEDGMENTS

This work was partially funded by the German Research Society (DFG) under grant GK-1042 (Research Training Group "Explorative Analysis and Visualization of Large Information Spaces"), and by the Priority Program (SPP) 1335 ("Visual Spatio-temporal Pattern Analysis of Movement and Event Data").

REFERENCES

[1] G. Andrienko, N. Andrienko, P. Jankowski, D. Keim, M. Kraak, A. MacEachren, and S. Wrobel. Geovisual analytics for spatial decision support: Setting the research agenda. *International Journal of Geographical Information Science*, 21(8):839–857, 2007.
[2] C. Chen and R. Rothschild. An application of hedonic pricing analysis to the case of hotel rooms in Taipei. *Tourism Economics*, 16(3):685–694, 2010.
[3] P. Densham. Spatial decision support systems. *Geographical information systems: Principles and applications*, 1:403–412, 1991.
[4] D. Foster, R. Stine, and R. Waterman. *Business analysis using regression: A casebook*. Springer Verlag, 1998.
[5] B. Ghalia and P. Wang. Intelligent system to support judgmental business forecasting: the case of estimating hotel room demand. *IEEE Transactions on Fuzzy Systems*, 8(4):380–397, 2000.
[6] W. Hung, J. Shang, and F. Wang. Pricing determinants in the hotel industry: Quantile regression analysis. *Hospitality Management*, 29(3):378–384, 2010.
[7] S. Kisilevich, D. A. Keim, and L. Rokach. Geo-spade: A generic google earth-based framework for analyzing and exploring spatio-temporal data. In *12th International Conference on Enterprise Information Systems*, volume 5, pages 13–20, 2010.
[8] S. Lee and S. Jang. Room Rates of US Airport Hotels: Examining the Dual Effects of Proximities. *Journal of Travel Research*, 2010.
[9] B. Li, A. Ghose, and P. G. Ipeirotis. Stay elsewhere? improving local search for hotels using econometric modeling and image classification. In *11th International Workshop on Web and Databases (WebDB)*, 2008.
[10] S. Rosen. Hedonic prices and implicit markets: product differentiation in pure competition. *The Journal of Political Economy*, 82(1):34–55, 1974.
[11] C. Thrane. Examining the determinants of room rates for hotels in capital cities: The Oslo experience. *Revenue & Pricing Management*, 5(4):315–323, 2007.