A Fair Dynamic Pricing Policy for the Hotel Industry

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ABSTRACT

Online platforms play a crucial role in the modern practices employed by the Hotel industry. Specifically, more and more customers turn to such platforms to book rooms and manage their reservations. Thus, adopting sophisticated pricing policies is inevitable since platforms offering the best prices are more likely to attract customers. At the same time, online platforms need to attract also room providers, and therefore the chosen pricing policies need to offer profits appealing to them. As such the pricing policies employed by the platform shall deal with the trade-off between offering rooms at low prices in order to attract customers and allowing large margin profits in order to attract room providers. In this work, we propose a multi-sided fair dynamic pricing policy that deals with this trade-off. Specifically, our policy *(i)* recommends room prices that reflect the quality of each hotel (with quality being related to a hotel's occupancy); *(ii)* avoids overpricing and underpricing, i.e., excessively high prices that cannot be justified by the quality of the hotel or irrationally low prices that cannot cover their costs; and *(iii)* ensures that all providers receive profit gains that are indicative of the quality of their product.

KEYWORDS

Dynamic Pricing, Fairness, Hotel Recommendations

ACM Reference Format:
Errikos Streviniotis, Athina Georgara, Filippo Bistaffa, and Georgios Chalkiadakis. 2023. A Fair Dynamic Pricing Policy for the Hotel Industry. In *Appears at the 5th Games, Agents, and Incentives Workshop (GAIW 2023). Held as part of the Workshops at the 21st International Conference on Autonomous Agents and Multiagent Systems., London, England, May-June 2023*, IFAAMAS, 3 pages.

1 INTRODUCTION

Nowadays, there has been a significant increase in the use of online platforms, due to the ease and convenience they provide to customers. As a result, individuals can exploit a wide range of products and services that are available on the web and choose items that best fit their interests or needs. For example, Amazon or eBay are representative examples of platforms that help users purchase products of various types. At the same time, Airbnb and Booking.com assist individuals in selecting the most appropriate room or apartment for their next trip by presenting them with a vast selection of options at competitive prices. Thus, online platforms have become an integral part of the modern economy, providing *(i) customers* the opportunity to peruse a vast number of options available at competitive prices; and *(ii) providers* the opportunity to access a vast pool of potential consumers.

One critical component of such platforms is the *pricing policy* that will be adopted to determine a specific item's price since it plays a significant role in shaping users' experience. In particular, it is expected that platforms that adopt (perceived) unfair pricing policies tend to suffer long-term losses since users will eventually turn to other, more favourable to them, platforms. As such, several pricing policies have been adopted by online platforms based on their type and their business model. For instance, Amazon utilises a dynamic pricing policy to adjust the price of a specific product in real-time based on market demand; Spotify offers fixed pricing plans that allow customers to access their content, while others allow buyers and sellers to negotiate about the price of a specific product. In the Hotel industry domain, the vast majority of platforms adopt some *dynamic pricing policy* aiming to balance the trade-off between optimising the revenue for hotels and offering low prices to the customers. However, the current dynamic pricing policies adopted by online platforms for the lodging industry [2]—the focus of our work here—have arguably yet to reach maturity. Specifically, only a handful of works address both the concepts of (perceived) fairness and the pricing policy, published before 2007 [5].

Against this background, we focus on the fairness aspect of online platforms in the hotel industry domain by proposing a game theory-inspired fair dynamic pricing policy. Specifically, given a collection of rooms organised in hotels—where the hotels correspond to providers—our policy adjusts the price of each room based on the supply and demand in the platform. Cooperative game theory [3, 9] and multi-agent systems [12] offers an appropriate framework for modelling such settings: In settings with many players (i.e., rooms) organised into groups (i.e., rooms belonging to the same hotel), the final payoff share of each player can be naturally determined based on the group they belong to and the other groups formed. Thus, in this paper, we model our problem as *a cooperative game* and exploit an appropriate solution concept to promote fairness.

Appears at the 5th Games, Agents, and Incentives Workshop (GAIW 2023). Held as part of the Workshops at the 21st International Conference on Autonomous Agents and Multiagent Systems., Abramowitz, Aziz, Ceppi, Dickerson, Hosseini, Lev, Mattei, Tsang, Wąs, Zick (Chairs), May-June 2023, London, England. © 2023 Copyright held by the owner/author(s).

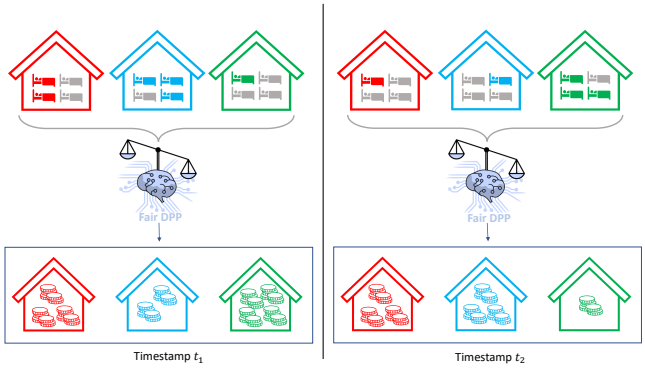

Figure 1: Fair Dynamic Pricing Policy: adjusting room prices based on supply, demand and occupancy rates on different timestamps. (Gray beds correspond to reserved rooms.)

2 WHY TO BE FAIR IN AN UNFAIR WORLD?

In general, during periods of high demand, as a rule of thumb, hotels tend to overprice their rooms. Thus, they set their room rates at a level that is significantly above the normal market value, often to take advantage of visitors who are obliged to pay a premium for accommodations during busy seasons. However, such a practice may result in hotel rooms being priced beyond what many individuals can afford, leading to potential discrimination against low-budget visitors. Thus customers that cannot afford the overpriced rooms are provided with limited accommodation options and reduced travel quality. Moreover, it is well-documented that expensive tourist destinations are associated with increased living costs and housing prices in the local communities [7], which can, in turn, contribute to the displacement of local residents from tourism destinations [4] and to the increase in inequalities [11].

Governments and local authorities could adopt measures to prevent overpricing of hotel rooms during such high-demand seasons. These measures may include implementing regulations on dynamic pricing and increasing transparency in pricing. In particular, *regulations* on dynamic pricing can ensure that prices are not increased too rapidly or too high. On top of that, *transparency* in pricing can help consumers make informed decisions by providing information about historical pricing patterns and rate increases. Such measures can promote fairness and affordability for consumers while still allowing hotels to operate profitably.

Regarding social good, preventing room overpricing during high-demand seasons can benefit the local community as well. Firstly, it can make the destination more accessible and affordable for a broader range of visitors, promoting a more inclusive tourism industry. This can lead to increased visitor numbers and revenue for local businesses. Additionally, it can help alleviate the negative impacts of high-end tourism on the local community, such as pushing out residents or small businesses due to increased rent and living costs.

3 A MULTI-SIDED FAIR DYNAMIC PRICING POLICY

In this section, we outline a fair dynamic pricing policy for the hotel industry. In particular, we propose a policy sketch for adjusting, in a fair way, the room prices over time, based on supply and demand. To begin with, we consider an online platform (which we refer to as system) that hosts hotels and rooms. Each room belongs to a specific hotel. Customers make their room reservations through this system, and they can reserve a room for any future date if one is available. When an available room is being reserved—or when a reserved room is cancelled—the dynamics between the hotels change, making some hotels more popular than others. As the free market economic model suggests, such changes in the popularity among providers should be reflected in the room prices. However, in our view, the room prices shall not exhibit arbitrarily large increases. Instead, they should follow the *relative power* (i.e., the *relative popularity*) of the hotels and adjust the room prices accordingly. That is, when adjusting the room prices, we should balance the trade-offs between allowing a popular hotel to claim larger profits and ensuring that the customers are offered rooms at prices proportional to the power of the room (i.e., how popular the respective hotel is). We highlight that, in our view, better quality items (i.e., rooms) should be allowed a larger profit margin (per available item), as that would increase the overall quality of the platform; while poor-quality providers will be motivated to improve their own product's quality. Notably, in this work, we assume that popularity is an indicator of high quality.

As such, our proposed policy aims to offer *fair* room prices under the following line of thinking:

(I) providers of high-quality items should be awarded;
(II) quality, supply and demand determine the rooms' power, which should be reflected in the price; and
(III) profit margins should be proportional to rooms' power.

Figure 1 depicts the general idea of our approach by presenting a toy example. In more detail, we assume that the market consists of three hotels, h_{red}, h_{blue} and h_{green}, each of which has 4 rooms. Now, at timestamp t_1 we can observe that h_{green} has 75% occupancy rate, i.e., only one un-reserved room and three reserved ones, while h_{red} and h_{blue} have 50% and 25% occupancy rates accordingly. Given these rates, our fair dynamic pricing policy provides proportional margins of profits to each provider. Thus, h_{green} has the largest margin of profit, followed by h_{red} and h_{blue}. Similarly, at timestamp t_2 we see that both h_{red} and h_{blue} achieve 75% occupancy rate and they share the same margin of profit based on our dynamic pricing policy. Finally, h_{green} has a 25% occupancy rate, and a lower margin of profit as a result. Note that by profit margin we refer to the potential profit for any available room in case this room is reserved at the recommended price.

Formally, let $H = \{h_1, \cdots, h_k\}$ be a set of hotels, where each hotel $h \in H$ represents a collection of rooms, and $R = \bigcup_{i=1}^{n} h_i$ be the set of all rooms hosted in the system. Moreover, let $T = \{t_1, t_2, \cdots\}$ be a timeline[1]. Now, we assume that there is a function $f : H \times T \to [0, 1]$, referred to as the supply and demand function, that captures the popularity of a hotel $h \in H$ at a timestamp $t \in T$, e.g. as the ratio of reserved rooms over the total number of rooms in the hotel. Function $g : H \times T \to [0, 1]$, referred to as the power index function, captures the relative power of each hotel $h \in H$ at timestamp $t \in T$ compared to the others within the system,

[1]For example, T may be the timeline of six months, and each timestamp $t \in T$ may represent a day or an hourly period.

given the supply and demand function. Note that the power of a hotel reflects the power of its rooms within the system. As a power index function g we can employ any existing function of choice originating in the economics and game theoretic literature, such as the Shapley-Shubick index [10], the Banzhaf index [1], the Johnson index [6], etc. Finally, function $u : R \times T \rightarrow \mathbb{R}^+$, referred to as pricing function, maps each room $r \in R$ with a price at timestamp $t \in T$, given the power index function g. Thus, our proposed pricing policy enables the designer to determine the exact nature of the functions for supply and demand, index power, and pricing, in order to satisfy the desired fairness criteria.

In our approach in this paper, we turn to cooperative game theory and in particular to the Owen value [8], in order to guarantee fair prices (or payoffs) for rooms (or players). The Owen value extends the Shapley value in order to allow for the fair allocation of payoffs to players in cooperative games *given* a particular coalition structure. Specifically, we view hotels as *coalitions* of available rooms and room types, and compute their Owen value. We subsequently exploit this fairness solution concept *in conjunction with* a novel graph-based representation scheme we put forward, in order to satisfy the three criteria mentioned above. The aforementioned representation scheme aids us in capturing *(i)* the hotel that each room belongs to; and *(ii)* common features that some rooms in a specific hotel may share, e.g., their type.[2]

3.1 Overview of main experimental findings

As part of this work, we conducted a thorough experimental evaluation to study the ability of our approach to provide prices that reflect the corresponding power of each hotel at a given time, based on supply and demand. Our results showed that our approach is able to recommend prices that are adjusted according to the supply and demand in the market and reflect the product's popularity—i.e., no room is either overpriced or underpriced, while it offers to each provider a margin of profits that is proportional to the quality of their product. Thus, our approach can be considered fair with respect to our definition, since it satisfies all the necessary conditions (see conditions (I), (II) and (III)) in the sketch of our fairness definition provided earlier in this section.

4 FUTURE WORK

Future work includes the employment of an exposure-opportunity policy that reflects the power of each hotel, i.e., high-quality hotels get more exposure opportunities compared to lower-quality hotels. Additionally, including machine learning models to extract pricing patterns based on historical data can help provide the platform's customers with relative information, and promote transparency and establish trustworthy platforms. Finally, an interesting line of research would be to consider the neighbourhood cost of living to achieve fair pricing for short-term rentals (hotels, Airbnb, etc.) and long-term ones (e.g., apartments and houses).

[2]Though the technical details of our approach were reviewed before acceptance of our originally submitted full paper in this workshop, we refrain from providing them in this publicly accessible document in order to not hinder their subsequent publication in venues with published proceedings.

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