Pricing Bundles for Airline Revenue Management

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1 Introduction

Revenue management (RM) has become a critical asset for airlines performances [1]. The common RM strategy used to be capacity based, where the overall supply (i.e. seats) is divided in a collection of classes with different costs and properties. These properties are defined by airline companies and describe how the classes are differentiated and which restrictions are imposed. They are finally used to decide which class must be opened for the sale.

The airline industry gradually started to move to dynamic pricing RM during the last decades, where the notion of class is no longer used and prices are freely chosen in real time. Dynamic pricing responds more precisely to market uncertainty, since the objective is to augment the price until it is no more acceptable for clients [2].

The clear advantages of RM and dynamic pricing led to the building of very mature and profitable models which allow to maximize the revenue for itineraries with different characteristics, but very few of these schemes consider the profitability of ancillaries (e.g. Wi-Fi). Historically, they have been neglected [3], even if the revenue obtained by the ancillaries increases year after year [4]. Recent airline marketing strategies are trying to push the purchase of ancillaries, since the marginal production cost is usually negligible, but they are seen very important by some customers. To ease the choice and improve the visualization, ancillaries are grouped and sold in pre-packaged bundles.

The main challenge lays in the choice of which bundles to show, given that there is a combinatorial number of possible ancillaries groups. Therefore, the bundles can't be easily shown to the end-user, and it makes sense to filter out the less profitable ones. This strategy opens up new profitable horizons, but also leads to more complex optimization approaches. Bundles can be seen as substitute products, i.e. same product (seat) with different variate (bundle). A dynamic pricing algorithm, with fixed products, is shown in [5].

2 Challenge and Contribute

In our work, we show that there exists a tractable dynamic programming algorithm to efficiently solve the dynamic pricing of substitute products for the one itinerary case: there is only one flight between two destinations. In the following we present our proposed method to find the best policy, i.e., which bundles should be shown to maximize the revenues.

Let $\mathcal{X}$ represent the set of all the possible combinations of seats occupancy and define $x \in \mathcal{X}$, where $x = (x_1, \ldots, x_K)$. Similarly, we also define the set of all possible bundles $\mathcal{B}$ and the set of all possible bundles given a specific occupancy state x_t with $\mathcal{B}(x_t)$, thus $\mathcal{B}(x) \subseteq \mathcal{B} \quad \forall x \in \mathcal{X}$. We also present u_i, that are the utilities associated to each bundle, where u_0 is the utility of no buy, and a_i is the quality index of bundle i. We assume that the selling time is divided in T time periods indexed in decreasing chronological order, hence the period T represents the end of the selling season and 0 is the initial day. The hypothesis is that only one customer arrives at each period, following a Poisson process. To solve the problem for substitute products, we use a multinomial logit model (MNL) model as utility model, where the probability that a customer chooses the bundle i is equal to $P_t^i(r_t)$ and the probability of no buy is $P_t^0(r_t)$. Thus, we have:

$$P_t^i(r_t) = \frac{\exp((a_i - r_t^i)/\mu)}{\sum_{j\in n} \exp(a_j - r_t^j)/\mu) + \exp(u_0/\mu)} \tag{1}$$

if we define $u_0 = a_i - r_t^i$ the expression can be rewritten as

$$P_t^i(r_t) = \frac{\exp(u_0/\mu)}{\sum_{j\in n} \exp(a_j - r_t^j)/\mu) + \exp(u_0/\mu)} \tag{2}$$

where μ is a scale factor.

We are therefore considering the stochastic optimization problem, represented with the Bellman equation provided in equation 3, with $\pi_0(x) = 0$

$$\pi_t(x) = \max_{B\in\mathcal{B}(x)} \max_{r_B\in\mathcal{R}_+^K} \sum_{i=1}^{B} P_t^i(r_t)\pi(t+1, x - e^i) \tag{3}$$

where B is a single bundle composed of some ancillaries. The problem is hardly tractable if directly solved with an approach like the one presented in [5]. The main challenge is that the inner optimization problem of the Bellman equation is non-trivial a priori, since there is not a way to directly calculate the bundles with the maximum revenues.

Our contribution states that the time complexity depends on the time period, the number of possible bundles and the dimension of the bundles:

Theorem 1 *The dynamic pricing of substitute bundles for the one itinerary case can be solved in $O(T|\mathcal{B}||B|)$.*

The proposed algorithm leads to an efficient solution of the problem and numerical results will be shown. As future work we would like to address a more general case of this RM problem, that it is to scale it to a full network where distinct aspect come into play, such as, for example, the competition between different companies or between several routes of the same company.

References

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