Dynamic assortment optimization based on customers behavior using transaction data

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Abstract

In this paper, we aim at investigating the impact of demand modelling on revenue performance for a shared mobility system. We consider the case where the information associated to the systematic part of the utility function is not available. We use dynamic assortment optimization to estimate utilities. We compare this assumption with the case where the choice probabilities are assumed to be static and homogenously estimated. The results indicate that this additional information helps to improve the service level as well as the revenue performance.

Introduction

Due to data science and technology development, app-based shared mobility system in urban transportation has received considerable attention. The foundation of app-based approach is based on the real-time interaction between the booking system and the users choice. When a user arrives in the system, she makes a request by identifying pickup, drop-off locations as well as preferred pickup time. A travel menu is then presented to the user and finally the user registers her choice in the system.

Inferring customer preferences and responding accordingly with updated product offerings plays an important role in a shared mobility system, especially as these companies are capable of revisiting product assortment based on the information they receive from the choice made by individuals. One of the central decisions is, which products to include in the list of offered ride alternatives to each arriving passenger in the list of assortments.

In most cases, it is assumed that the user behavior is known a priori mostly through surveys. Depending on the sample selection, the estimated parameters can cause revenue loss in designing the menu. On the other hand, the system has a privileged access to registered choice which can improve the estimation of parameters. The registered data reflects the choice of selected option over those offered in the menu. Therefore, the booking system needs to offer all possible combination of options in the menu to each user which first is computationally expensive and second each experiment results in revenue loss.

The underlying problem studied in this paper is to find the balance between the collected data and revenue performance. More specifically, we determine how to construct the travel menu (which options should be included) and how many experimental data are required.

Approach

For shared mobility system, the app-based assortment construction is threefold. First, there is no (or little) information about the users behavior. Second, there is substitution in travel options and the demand for individual option is affected by available alternatives on the constructed menu. Third, offering travel menu is a dynamic decision. The booking system has access to the users choice. It needs to decide which assortment to offer to each user to maximize the profit (dynamic assortment optimization).

In this paper, we assume that each user wishes to maximize her utility that can be assigned to either an available alternative or opt-out option. An alternative is selected if its associated utility has the highest value among all available choices. We model the users choice with multinomial logit. For each alternative, the observable part of the utility is not known in advance. However, the stochastic part of the utility follows a Gumbel distribution with known values. Therefore, the observable part must be estimated from customers choices.

We formulate the problem as a dynamic programing model. We then tackle two different research questions based on this model: either the model is used for data collection and parameter estimation or it is used to offer the optimal travel menu to maximize the revenue. In the first case, we analyze travel menus that are built based on the multinomial logit model. We then use a search algorithm to identify a sequence of menus to offer to the customer. In the second case, we present a set of policies to find a tradeoff between data collection and revenue maximization. For each policy, we show revenue performance over time and show the optimality gap. These gaps help us to determine when the data collection process should stop. We then present a search algorithm to formalize the procedure. With this algorithm, it is possible to directly estimate the utility of each option without knowing the contributing factors.

Results

The described methodology is coded in C++. We have considered simulated data for a city centre area in which requests arrivals varies during on-peak and off-peak hours. Two series of experiments are chosen to evaluate the performance of our model. In both cases, we have two customer segments in which the assignment of the customer to each segment is known.

In the first set of simulation our goal is to compare the performance of the approach in comparison with the case that estimate utility is known with certainty. We test our algorithm for the simulated data. In this case, for each group the estimated utility of each choice is known as well as the expected revenue. We test our approach to simultaneously estimate the choice parameters and optimize the travel menu. For our case study, the algorithm is able to achieve to correctly estimate the utility for 80% of the choices. Moreover, the expected profit is around 10% less than the expected one with complete information.

In the second set of experiments, we test our approach for static and dynamic case. In static case, we optimize the travel menu based on the estimated parameters come from travel surveys. In the dynamic case, we use the parameters as an initial value and use the algorithm to improve the estimation. For our test case, the algorithm modifies the utility values of the 34% of the offered choices. The modification range from 1 to 12% of the original value. We then compare these three cases of revenue: the static case, the dynamic case and the static case using the parameters obtained by dynamic one. The results indicate that the expected revenue can improve 5% by learning from travellers choice.

Conclusion

In this paper, we present an approach that can simultaneously learn from travellers choice by offering them in different traveling menus. We present the application of this approach on on-demand shared mobility system. The model assumes no prior knowledge of consumer behaviour and the goal is to minimize the loss by finding the trade-off between the number of experiments and the correctness of the parameter estimation. We present a series of policies to quickly identify the best travel menu to the customer. With the presented approach, we are able to reduce the complexity of data collection problem. We devise two series of simulation experiments to evaluate the performance of our approach. We have also tested this model by using the estimated parameters enabling us to modify the estimations and improve the revenue by 5% by learning from travellers choice.