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DYNAMIC CONGESTION PRICING FOR RIDESOURCING TRAFFIC: A SIMULATION OPTIMIZATION APPROACH

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ABSTRACT

Despite the documented benefits of ridesourcing services, recent studies show that they can slow down traffic in the densest cities significantly. To implement congestion pricing policies upon those vehicles, regulators need to estimate the degree of congestion effect. This paper studies simulation-based approaches to address the two technical challenges arising from the representation of system dynamics and the optimization for congestion price mechanisms. To estimate the traffic state, we use a metamodel representation for traffic flow and a numerical method for data interpolation. To reduce the burden of replicating evaluation in stochastic optimization, we use a simulation optimization approach to compute the optimal congestion price. This data-driven approach can potentially be extended to solve large-scale congestion pricing problems with unobservable states.

1 INTRODUCTION

Ridesourcing (also termed as ridehailing or for-hire ridesharing) generate excess traffic congestion due to deadhead trips and cruising for customers on traffic-clogged streets. For instance, San Francisco County Transportation Authority (SFCTA) found that Transportation Network Companies (TNC) vehicle fleet (e.g., Uber, Lyft) accounted for approximately 50 percent of the rise in congestion in San Francisco between 2010 and 2016 (SFCTA 2019). Although as an arising business model, ridesourcing brings forth customer's surplus, the increasing traffic congestion has induced substantial negative externalities to other road users. Therefore, government agencies worldwide are considering carrying out new regulatory policies on the ridesourcing traffic.

The current practice is simply imposing a cap on for-hire vehicles in cities (NYT 2018). A fixed quantity-based policy, however, may harm the satisfaction of the urban transportation ecosystem. Preferably, a government agency can use a dynamic congestion pricing (DCP) policy that control the ridesourcing traffic by monetizing the internal costs generated by traffic congestion, and then impose the costs externally on certain routes or links. Such external costs can discourage the excess travel demand in the highly congested regions or during the peak hours.

Nevertheless, implementing DCP for ridesourcing traffic is not a trivial task (Lehe 2019). The difficulty can be compounded by two factors: (a) Lack of traffic data for each subgroup of road users; (b) Intractable optimization due to the unpleasant properties of the objective function. In other words, from the partially observed data (e.g., sensory data at fixed locations, and trajectory of sample vehicles). we shall estimate how badly the traffic congestion is caused by ridesourcing.

2 METHODS

Our solution for the former challenge is using a metamodel representation (i.e., stochastic kriging model) within a traffic state estimation model. This estimation model can predict the traffic condition one-step ahead by a computationally expensive partial differential equation approach .

Such a complex representation model makes the pricing optimization part even harder to solve. Hence, we use a Bayesian optimization approach to handle the latter challenge. In the end, we are able to solve the DCP in nearly real-time for each link, which becomes a more practical and implementable policy instrument for regulations.

3 RESULTS AND CONCLUSION

We implement the proposed simulation optimization approach in a toy example (two classes of vehicles circling on a closed ring road). In addition, we compare out approach with a simple regression model. It turns out that regression model can either significantly overestimate or underestimate the true congestion state, and hence impose inappropriate DCP policies. With a fine prior fundamental diagram (i.e., the relationship between average speed and traffic density), our approach is superior in both traffic state estimation and pricing optimization.

We conclude with two main findings. First, traffic state estimation and pricing optimization can be integrated properly in a simulation optimization scheme. Second, considering the estimation and optimization problem separately may undercharge or overcharge congestion prices in practice. The latter finding is coincided with the recent policy-makers and regulated companies' conflicts regarding the data-sharing issues. It suggests that there is a solution to find an effective policy with a privacy-preserving database.

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