Dynamic Assignment for a Crowdshipping Platform

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Driven by the growth of online shopping, parcel delivery has grown rapidly in recent years, resulting in an increased demand for cost-efficient last-mile delivery [3]. At the same time, the question of sustainability is increasingly present in logistics and in society in general.

Crowdshipping applies the concept of crowdsourcing to the personalized delivery of freight, turning ordinary citizens into couriers for the distribution of small items. In this collaborative delivery system, individuals already traveling from an origin to a destination take charge of all or part of the delivery, taking a package along with them and making a stop along the way to drop it off. In a successful implementation, crowdshipping reduces the number of freight delivery trucks, benefiting companies by reducing their delivery costs, as well as improving sustainability [4].

The matching of crowdshippers to parcels as they appear in real time is key for crowdshipping to yield its intended effects. Indeed, the high degree of uncertainty inherent to crowdshipping, primarily in crowdshippers' and parcels' availability, can result in high operational costs and low service reliability [2]. In determining the assignment of crowdshippers to parcels over time, the main questions are as follows: (1) To which crowdshipper should we assign the parcels? (2) Should we postpone some delivery in the hope for a future crowdshipper with a shorter detour? (3) How can we consider the future uncertainty and downstream cost in real-time decision making? (4) Can we increase the total number of served parcels and/or decrease delivery distance by making smarter assignment decisions?

Interestingly, the majority of research on crowdsourced transportation does not directly address the challenges of uncertain availability, but rather assume perfect information. Studies that incorporate the uncertainty in crowdshipping operations are scarce, and only few of those consider a dynamic problem setting (e.g., [1]; [5]; [7]; and [2]). Recent works by Mousavi et al. [2] and Dayarian and Savelsbergh [1] are the closest to ours. However, both consider in-store customers as crowdshippers to deliver groceries within few hours.

Our article focuses on crowdshippers with any origin and destination, and longer distances. Crowdshippers are known in advance, enabling planning and decision-making more ahead of time. Exogenous information relative to the arrival and disappearance of parcels and crowdshippers is observed throughout the day. At the beginning of each day, decisions regarding the assignment of crowdshippers to parcels are made among those available. Then at the end of the day, based on the decisions and observed exogenous information, the state of the system is updated. The dynamic assignment problem considered in our article therefore consists of solving a sequence of crowdshipper-to-parcel assignment problems over time, with both crowdshippers and parcels arriving randomly over time. By their very nature, crowdshippers will only be available a single day, while parcels have a delivery window. This problem can be classified as a discrete time sequential stochastic decision problem, that we formulate as a discrete time Markov decision process.

Due to the "curse of dimensionality", the model is not solved with conventional dynamic programming methods. The proposed algorithm uses an Approximate Dynamic Programming (ADP) approach based on Value Function Approximation (VFA) [6]. It is based on offline learning of value functions through simulation of the problem's Markov decision process. This adaptive learning algorithm provides nonmyopic behavior yet requires only solving sequences of assignment problems no larger than would be required with a myopic algorithm.

Our first numerical results show the efficiency of our algorithm in comparison with myopic solutions on small instances. We compare the performance of our algorithm against both myopic and perfect-information approaches. The comparison is made in terms of the number of parcels handled by crowdshipping, as well as of the reduction of the delivery distance.

References

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