Single-Leg Revenue Management with Advice

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Single-leg revenue management is a foundational problem of revenue management that has been particularly impactful in the airline and hotel industry: Given n units of a resource, e.g. flight seats, and a stream of sequentially-arriving customers segmented by fares, what is the optimal online policy for allocating the resource. Previous work focused on designing algorithms when forecasts are available, which are not robust to inaccuracies in the forecast, or online algorithms with worst-case performance guarantees, which can be too conservative in practice. In this work, we look at the single-leg revenue management problem through the lens of the algorithms-with-advice framework, which attempts to harness the increasing prediction accuracy of machine learning methods by optimally incorporating advice about the future into online algorithms. In particular, we develop online algorithms which optimally trade-off consistency (performance when advice is accurate) and competitiveness (performance when advice is inaccurate) for *every advice*. Our results extend to other unit-cost online allocations problems such as the display advertising and the multiple secretary problem together with more general variable-cost problems such as the online knapsack problem.

Consistency-Competitiveness Pareto Frontier. We construct an LP, and develop an optimal algorithm based on it, that completely characterizes the Pareto frontier of consistency and competitiveness. More precisely, we give an efficient LP-based optimal algorithm which, given an advice and a required level of competitiveness, achieves the highest level of consistency on that advice among all online algorithms that satisfy the required level of competitiveness.

Optimal Protection Level Policy. We also study the class of protection level policies, which is the most widely-deployed technique for single-leg revenue management: we provide an algorithm to incorporate advice into protection levels that optimally trades off consistency and competitiveness. Our numerical evaluation on synthetic data reveals that our algorithm for protection level policies performs remarkably well on most instances, even if it is not guaranteed to be on the Pareto frontier in theory.

Robustness. Since no prediction algorithm can be completely accurate, it is also important for any algorithm to achieve good performance when the sequence of fares is "close" to the advice. We use an appropriately modified ℓ_1 norm to define a distance between the realized fare sequences and the advice, and show that the performance of our algorithms degrades gracefully as a function of this distance.

A full version of this paper can be found at https://arxiv.org/abs/2202.10939.

CCS Concepts: • **Theory of computation → Online algorithms**.

Additional Key Words and Phrases: online resource allocation, algorithms with predictions, pareto-frontier

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