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From Contextual Data to Newsvendor Decisions: On the Actual Performance of Data-Driven Algorithms

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In this work, we explore a framework for contextual decision-making to study how the relevance and quantity of past data affects the performance of a data-driven policy. We analyze a contextual Newsvendor problem in which a decision-maker needs to trade-off between an underage and an overage cost in the face of uncertain demand. We consider a setting in which past demands observed under "close by" contexts come from close by distributions and analyze the performance of data-driven algorithms through a notion of context-dependent worst-case expected regret. We analyze the broad class of Weighted Empirical Risk Minimization (WERM) policies which weigh past data according to their similarity in the contextual space. This class includes classical policies such as ERM, k-Nearest Neighbors and kernel-based policies. Our main methodological contribution is to characterize exactly the worst-case regret of any WERM policy on any given configuration of contexts. To the best of our knowledge, this provides the first understanding of tight performance guarantees in any contextual decision-making problem, with past literature focusing on upper bounds via concentration inequalities. We instead take an optimization approach, and isolate a structure in the Newsvendor loss function that allows to reduce the infinite-dimensional optimization problem over worst-case distributions to a simple line search. This in turn allows us to unveil fundamental insights that were obfuscated by previous general-purpose bounds. We characterize actual guaranteed performance as a function of the contexts, as well as granular insights on the learning curve of algorithms.

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