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Data-Efficient Quickest Change Detection with On-Off Observation Control

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In this paper we extend the Shiryaev's quickest change detection formulation by also accounting for the cost of observations used before the change point. The observation cost is captured through the average number of observations used in the detection process before the change occurs. The objective is to select an on-off observation control policy, that decides whether or not to take a given observation, along with the stopping time at which the change is declared, so as to minimize the average detection delay, subject to constraints on both the probability of false alarm and the observation cost. By considering a Lagrangian relaxation of the constraint problem, and using dynamic programming arguments, we obtain an \textit{a posteriori} probability based two-threshold algorithm that is a generalized version of the classical Shiryaev algorithm. We provide an asymptotic analysis of the two-threshold algorithm and show that the algorithm is asymptotically optimal, i.e., the performance of the two-threshold algorithm approaches that of the Shiryaev algorithm, for a fixed observation cost, as the probability of false alarm goes to zero. We also show, using simulations, that the two-threshold algorithm has good observation cost-delay trade-off curves, and provides significant reduction in observation cost as compared to the naive approach of fractional sampling, where samples are skipped randomly. Our analysis reveals that, for practical choices of constraints, the two thresholds can be set independent of each other: one based on the constraint of false alarm and another based on the observation cost constraint alone.

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