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A SIMULATION-BASED APPROACH TO STATISTICAL INVENTORY MANAGEMENT

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ABSTRACT

Most of the literature on inventory management assumes that the demand distribution and the values of its parameters are known with certainty. In this research we consider the practical situation where this is not the case and only a limited amount of autocorrelated demand data are available. Assuming an autocorrelated demand process represented by the highly flexible Autoregressive-To-Anything (ARTA) time series (Cario and Nelson 1996), we study the problem of estimating inventory targets from limited historical demand data. By also modeling the marginal demand distribution with the Johnson Translation System (Johnson 1949), we capture a wide variety of distributional shapes and obtain an input demand model generalizing the linear auto-regressive process, which is widely used in inventory management despite implying a normal marginal demand distribution – an assumption often violated by real-world demand data sets.

We consider a single-period newsvendor inventory problem, but under the assumption that the parameters of the input demand model are unknown. The optimal number of units to keep in inventory is well known with complete knowledge of the demand distribution. However, the implementation of the optimal solution by treating the estimates of the unknown input parameters (obtained from limited amount of historical demand data) as if they were the true values is not necessarily optimal. Hayes (1969) pioneers the quantification expected cost of parameter uncertainty in inventory management by assuming that the demand distribution is either exponential or normal. Akcay, Biller, and Tayur (2011) extend this approach by modeling the demand with Johnson Translation System to account for the impact of distributional shape on the expected cost of parameter uncertainty under an independent and identically distributed demand setting. In this research, however, we use a sampling algorithm based on Monte Carlo simulation, and quantify the expected cost of parameter uncertainty as a function of not only the length of the historical demand data, the inventory holding and shortage costs, the parameters of the Johnson demand distribution, but also the autocorrelation of the demand process. We study the impact of the demand autocorrelation on the inventory-target estimation and discuss when the autocorrelation in the demand process can be ignored, despite its existence, in the presence of limited demand data. We determine the improved inventory-target estimate accounting for this parameter uncertainty via sample-path optimization. Our procedures can be easily implemented in practical settings with reduced expected total operating cost which not only captures the stochastic demand uncertainty but also the demand parameter uncertainty. For example, an inventory manager who builds the inventory target by simply using the estimates of the demand parameters as if they were the true values may end up with 81% greater expected cost than the optimal inventory target when the autocorrelation is 0.9. In this particular case, we further see that the use of improved inventory-target estimate eliminates 56% of the expected cost due to parameter uncertainty.

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