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Title: The multilevel bootstrap particle filter

Abstract:
Multilevel Monte Carlo methods were first popularised within the setting of financial mathematics to estimate the expected value of some payoff function of interest, but the multilevel approach is applicable to a far wider class of problems. This approach can be summarised as performing decreasing numbers of simulations at increasing levels of cost to reduce the Monte Carlo variance of the estimator. We develop this approach within the setting of sequential Monte Carlo methods (SMC) to obtain the multilevel bootstrap particle filter (MLBPF). SMC methods are often the only feasible way to estimate the distribution of a partially observable, latent Markov process. In the event that the likelihood model is expensive to evaluate, generation of the importance weights can entail computational times that are impractically long for real-time applications, particularly when a large number of particles are required. To reduce this burden, we adopt the multilevel approach to achieve more accurate approximations to the posterior than the traditional bootstrap particle filter (BPF) at equivalent computational cost. We establish a strong law of large numbers and central limit theorem that prove convergence of the MLBPF for bounded and measurable test functions, and provide some applications where the MLBPF empirically outperforms the BPF.