Fixed rank filtering for spatio-temporal data

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Abstract

Datasets from remote-sensing platforms and sensor networks are often spatial, temporal, and very large. Processing massive amounts of data to provide current estimates of the (hidden) state is challenging, even for the Kalman filter. A large number of spatial locations observed through time can quickly lead to an overwhelmingly high-dimensional statistical model. Dimension reduction without sacrificing complexity is our goal in this article. We demonstrate how a spatio-temporal random effects (STRE) component of a statistical model reduces the problem to one of fixed dimension with a very fast statistical solution, namely fixed rank filtering (FRF). This is compared to successive, spatial-only predictions based on an analogous spatial random effects (SRE) model, and the value of exploiting temporal dependence is demonstrated. A remote-sensing dataset of aerosol optical depth (AOD), from the Multi-angle Imaging SpectroRadiometer (MISR) instrument on the Terra satellite, is analyzed using FRF. We achieve rapid production of optimal, gap-filled, filtered AOD predictions, along with their prediction standard errors, and demonstrate their superiority over successive, spatial-only AOD predictions when there are large gaps in the current data. We processed over 100,000 spatio-temporal data: parameter estimation took 54.8 seconds to compute, and predictions and their standard errors took 11.2 seconds to compute.