

Article

State Space Modeling of Event Count Time Series

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Abstract: This paper proposes a class of algorithms for analyzing event count time series, based on state space modeling and Kalman filtering. While the dynamics of the state space model is kept Gaussian and linear, a nonlinear observation function is chosen. In order to estimate the states, an iterated extended Kalman filter is employed. Positive definiteness of covariance matrices is preserved by a square-root filtering approach, based on singular value decomposition. Non-negativity of the count data is ensured, either by an exponential observation function, or by a newly introduced “affinely distorted hyperbolic” observation function. The resulting algorithm is applied to time series of the daily number of seizures of drug-resistant epilepsy patients. This number may depend on dosages of simultaneously administered anti-epileptic drugs, their superposition effects, delay effects, and unknown factors, making the objective analysis of seizure counts time series arduous. For the purpose of validation, a simulation study is performed. The results of the time series analysis by state space modeling, using the dosages of the anti-epileptic drugs as external control inputs, provide a decision on the effect of the drugs in a particular patient, with respect to reducing or increasing the number of seizures.

Keywords: nonlinear state space model; iterated extended Kalman filter; Bayesian filtering; count time series; singular value decomposition



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1. Introduction

Temporal data sequences resulting from counting discrete events over a given time interval represent a particular variant of time series called discrete-valued or event count time series. These count data arise in various fields, such as physics, epidemiology, finance, econometrics, or medicine. Much of the existing framework on time series analysis relies on the assumptions of Gaussianity and linearity. The non-negativity and integrity constraints inherent in count time series have led to the development of alternative modeling approaches that instead employ probability distributions of Poisson type. As prominent examples we mention generalized linear models (GLMs) [1], dynamic generalized linear models [2,3], integer-valued autoregressive (INAR) models [4], and integer-valued generalized autoregressive conditional heteroscedasticity (INGARCH) models [5–7].

However, in this paper we aim at modeling count time series within the linear Gaussian regime as long as possible, while introducing non-negativity and integrity only at the last stage of modeling, namely, at the stage of modeling the observation process. The suitable framework for this agenda is given by classical state space modeling [8]. In state space modeling, the dynamical process underlying the data is explicitly separated from the observation process, such that the former can be kept Gaussian and linear, which considerably simplifies state estimation and model identification. Further advantages of the state space approach are given by the possibility to discriminate between dynamical noise and observation noise, and by the option of straightforward generalization to the multivariate case.

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