Biomedical applications of time series analysis

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ABSTRACT

Many biomedical data are available as time series, especially in the field of public health and epidemiology, where indicators are usually collected over time. Clinical studies with long follow-up are also sometimes best analyzed with time series methods. The analysis of administrative health care data often gives rise to time series problems too, as events are frequently converted to counts over a given interval. Finally, some biomedical measurements also may be viewed as time series, such as ECG recordings.

The methods of time series analysis can be very broadly divided into two categories: time-domain and frequency-domain methods.

Frequency-domain methods are based on converting the time series, classically using Fourier transform, to a form where the time series is represented as the weighted sum of sinusoids [1]. This so-called spectral analysis allows us to get insight into the periodic components of the time series, making it possible to investigate cyclicity/seasonality of the original data. Fourier transform, however, does not allow the spectrum to evolve over time, so methods were developed which make a trade-off between time resolution and frequency resolution, such as wavelet analysis [2]. In addition to the investigation of periodicity in epidemiologic data (e.g. [3]), these methods are also widely used in biomedical signal analysis, such as the analysis of ECG recordings [4].

The vast majority of time series analyses, however, apply time-domain methods. Roughly speaking, they can be divided into "classic" time series regression methods employing only exogenous regressors (which may include long-term secular trend and seasonality in epidemiology, patient characteristics in a clinical study, or the past or contemporary value of another time series that is possibly related to the one under investigation, this can include an abrupt change giving rise to segmented regression models) and methods with stochastic component (autoregressive and moving average models, and their combinations). In epidemiology, regression models are often complicated by the fact that the response variable is count data, giving rise to generalized linear models, the presence of overdispersion [5], and non-linearities [6]. These methods are often used today, from environmental epidemiology [7] to infectious diseases modelling [8].

One profound problem in time series modelling is the presence of autocorrelation. To capture the dynamics of the time series, ARIMA-models (Box-Jenkins approach) are often used in other areas; this started to appear in medicine too [9].

Other, biomedically less often used applications of time series methods include filtering/smoothing, the analysis of multivariate time series (such as VAR-models), and more complex state space models.

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