Robust Estimation of the Scaling Exponent in Detrended Fluctuation Analysis of Beat Rate Variability

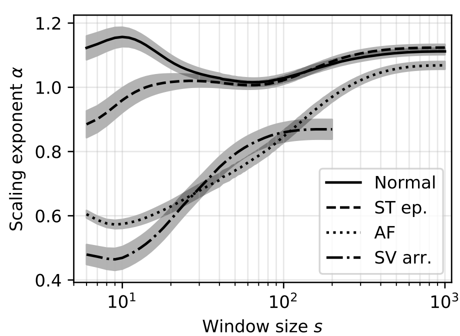
Matti Molkkari, Esa Räsänen

Tampere University of Technology
Tampere, Finland

Detrended fluctuation analysis (DFA) is a popular method for studying fractal scaling properties in time series. The method has been successfully employed in studying heart rate variability and distinguishing different pathological conditions by means of scaling exponents. Traditionally the analysis has been performed by extracting two scaling exponents from linear fits, for short- and long-range correlations respectively. The extent of these ranges is subjective and the linear two-range model potentially disregards additional information present in the data.

Here we present an optimization scheme based on integer linear programming for segmenting the DFA fluctuation function into data-adaptive number of local linear fits. Additionally, we present methods based on the Kalman filter and smoother for obtaining a whole spectrum of scaling exponents as a function of the DFA window size. These methods provide parameter-independent robust estimates for the scaling exponent that are resistant to statistical noise in the fluctuation function, while remaining sufficiently sensitive to capture local variations in the scaling exponent. The fluctuation function exhibits scaling exponent-dependent bias in small window sizes. Obtaining continuous estimates for the scaling exponent allows iterative refinement of the fluctuation function to compensate for the bias.

These methods are employed in the analysis of the heart rate variability of patients with different pathological conditions. The methods provide mutually consistent results and reveal more complex structure in the scaling exponent beyond the two-range model.



The means and their standard errors for Kalman smoother estimates of the DFA scaling exponent for RR intervals of patients with various conditions from PhysioBank data.