Time series analysis by singular spectrum methods: Application to the processing of acoustic emission signals

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Several methods using the Fourier transform or the time-frequency decomposition can be used to analyze and process acoustic emission (AE) signals. Most of them are based on specific assumptions on the stochastic behavior of the source signal or the noise. For example, in a denoising problem, a method like the spectral subtraction assumes that the noise is a stationary random process. In general, since acoustic emission data are closely linked to the experimental protocol that allows their recording, their stochastic behavior also depends on this experimental protocol. Therefore, it is relevant to test processing methods that make no assumption on the stochastic behavior of the noise or the source signal and are potentially efficient for any signal pattern.
The Singular Spectrum Analysis (SSA) method has received increasing attention since the early nineties. Recently it has been successfully applied to various topics, for instance in geophysics and economics. Unlike most methods for time series analysis, SSA needs no statistical assumption on signal or noise, while performing analysis and investigating the properties of the algorithm. By using a decomposition of the signal into the sum of a small number of independent and interpretable components, SSA allows to perform various tasks such as extraction of specific components from a complex signal (noise, trend, seasonality ...), detection of structural changes and missing values imputation. To our best knowledge, very few works have explored the ability of the SSA to analyze and denoise AE signals. This is the main objective of this work.
Several tools based on the classical SSA are tested. The results obtained with simulated data match with those obtained with real data from nuclear safety experiments. In both cases, analysis of the heterogeneity matrix (H-matrix) leads to the identification of the main components of the corrupted signal, even for low signal-to-noise ratio. The H-matrix also allows the estimation of the correlation (in terms of heterogeneity) between these components. For signal denoising purposes, the SSA leads to an excellent estimation of the source signal when the separability between the noise and the source signal is such that the weighted correlation tends to zero. However, denoising becomes more difficult with increasing weighted correlation. We observe waveform distortions of the source signal and some artifacts are created when the noise and the source signal share some frequency range.

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