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WAVEPAL: A Software for Frequency and Wavelet Analysis of Irregularly Sampled Time Series

Guillaume Lenoir (1) and Michel Crucifix (1,2)
(1) Université Catholique de Louvain, Earth and Life Institute, (2) Belgian National Fund of Scientific Research

WAVEPAL is based on a general theory that we have developed for the frequency and wavelet analysis of irregularly sampled time series. It is based on the Lomb-Scargle periodogram, that we extend to algebraic operators accommodating for the presence of a polynomial trend in the model for the data, in addition to the periodic component and the background noise. Special care is devoted to the correlation between the trend and the periodic component. This new tool is then cast into the formalism of the Welch overlapping segment averaging (WOSA) method, which is used to reduce the variance of the periodogram/scalogram. We also design a test of significance against a background noise which is a continuous autoregressive-moving-average (CARMA) Gaussian process. This widens the traditional choice of a Gaussian white or red noise process as the background noise. Estimation of CARMA parameters is performed in a Bayesian framework and relies on state of the art algorithms. We then provide algorithms computing the confidence levels for the periodogram/scalogram that fully take into account the uncertainty on the CARMA noise parameters. Alternatively, if one opts for the traditional choice of a unique set of parameters for the CARMA background noise, we develop a theory providing analytical confidence levels, which are more accurate than Markov chain Monte Carlo (MCMC) confidence levels and, below some threshold for the number of data points, less costly in computing time. We then estimate the amplitude of the periodic component with least squares methods, and derive an approximate proportionality between the squared amplitude and the periodogram/scalogram. The estimated signal amplitude also gives access to ridge filtering or filtering in a frequency band. Our results generalize and unify methods developed in the fields of geosciences, engineering, astronomy and astrophysics. WAVEPAL is written in python2.X and is available at https://github.com/guillaumelenoir/WAVEPAL