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Spectral analysis of nonuniformly sampled data series: smoothing and improving resolution of spectral estimates by combining information from multiple series

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In the last decade numerous papers were devoted to methods of spectral analysis for nonuniformly sampled data mainly due to the importance of the subject not only to astronomy but also to many other areas as geophysics, genetics, and paleoclimatology. Since then the periodogram has been used for this purpose and much effort has been spent in order to understand its behavior when applied to the arbitrarily sampled data case. The most controversial points are the properly choice of a grid in the frequency domain and the 'statistical significance' of any observed spectral feature. We present here a procedure based on the analysis of a set of contemporary series (multiple records of the same event) in which the individual spectra are combined in two different ways: an inclusive estimative containing all the recovered spectral information (or coherent features) – the 'OR' spectrum, and an exclusive estimative containing only the common recovered information from all series – the 'AND' spectrum.

After a properly choice of a working 'Nyquist frequency' (based on geometrical properties of the spectral window) and of a frequency resolution increment, the method consists basically of a Bayesian inversion of the state of information functions (freely normalizable probability distributions) based on the spectral properties of the unevenly sampled time series. This fully nonlinear solution incorporates principles of the holographic reconstruction method, and allows a much better mixture of spectral estimation uncertainties, improving resolution on coherent features and the signal-to-noise ratio. It is a kind of the so called 'stacking' in seismic but applied just in the frequency domain.

The main advantages of the method are: no need of any pre-treatment of data which can lead to dislocation of the main peaks in the spectrum; a very smoothed version of the final periodogram (degree of smoothness depending on how many short series are available to be combined) highlighting the common spectral features (periodicities); possibility to analyze short noisy series (in combination with longer ones), otherwise ignored for purposes of spectral analysis, highlighting resolution on longer periods.

The method was originally developed for investigating possible spatial patterns in the trajectories of the ancient earth's magnetic field pole as revealed by multiple paleomagnetic stratigraphic sequences (neighbor sequences). In most cases such records only poorly show the long term geomagnetic events (paleosecular variation, geomagnetic reversals and excursions) and do not allow to composition of the distinct curves point by point; therefore, a new analytical method able to deal with large and discrepant model uncertainties (in this case different spectral uncertainties) is claimed for, and Bayesian methods seem natural.

Potential applications of this method can be envisaged mainly in cyclostratigraphy, oceanography and meteorology.