32nd URSI GASS, Montreal, 19-26 August 2017

Ensemble Detection Analysis for Characterizing Non-Stationary Processes

Mustafa Aksoy*(1)(2), and Paul E. Racette(2)
(1) Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Baltimore, MD, USA
(2) NASA Goddard Space Flight Center, Greenbelt, MD, USA

1. Extended Abstract

There are many types of random processes and ways with which to describe them. A random process is stationary in the strict sense if its statistics are invariant to a shift in time (or origin). A process is called wide-sense stationary if its first and second moment statistics are invariant to a shift in time (or origin). A non-stationary process, however, has statistics that change with a translation of time (or origin). A process may be non-stationary in its first, second, or n^{th} moment statistics [1]. Some examples of non-stationary processes are: geophysical time series of temperature and rainfall, economic time series of Dow Jones Industrial Average, frequency variation in modern and traditional music, and spatial structure in natural terrain [2, 3]. Non-stationary processes that can be treated as stationary over short periods of time are called locally stationary [4]. One of the most confounding properties of non-stationary processes is that the statistics obtained from observations depend on the sampling and algorithm used for analysis, e.g. averaging window. Several methods such as wavelet-based approaches and the Hilbert-Huang Transform [5] have been used to model and analyze non-stationary processes.

Ensemble detection is a novel noise-assisted data analysis technique. The theoretical basis was derived by applying stochastic process theory to develop a generalized approach to examine uncertainty in radiometric measurements due to time varying receiver response and calibration algorithms [6]. The approach treats the time series of samples from a radiometer's calibration references as an ensemble set of realizations of the underlying receiver response, i.e. gain. The analytical approach was verified by experiment and lead to the invention of the ensemble detector [7]. An ensemble detector produces a set of realizations of a process by mixing observations from the process with wide sense stationary noise signals. The realizations comprise an ensemble set, which is admissible to statistical analysis and filtering algorithms that is otherwise not possible to implement using a single realization. Strict-sense and wide-sense stationary processes yield a-priori statistical relationships. Non-stationarity is thus quantified by deviations from the stationary assumption by applying functional algorithms with temporal dependency. The approach applies the concept of calibration to the characterization of non-stationary processes.

This presentation will describe the ensemble detection technique and its application to characterize the stationarity of random processes. Ensemble detection will be mathematically introduced and simulation results, which test and validate the mathematical description will be demonstrated. Finally, statistical properties of the temporal change in atmospheric temperatures measured in Ashton, KS between 1993 and 2016 will be discussed using Ensemble Detection.

2. References

1. M. B. Priestly,*Spectral Analysis and Time Series*, Academic Press, LTD, London England, 1992.

2. B. Mandelbrot, *The Fractal Geometry of Nature*, W.H. Freeman and Company, New York, NY, 1983, Chapters 1 and 2.

3. M. Andrecut, "1/f Noise in the 'Game of Life'," *Modern Physics Letters B*, **14(2)**, 2000, pp. 53-57.

4. J. S. Bendat, A. G. Piersol, *Measurement and Analysis of Random Data*, John Wiley and Sons, New York, NY, 1966, Chapter Nine.

5. N. E. Huang, Z. Shen, S. R. Long, M. C. Wu, H. S. Hsing, Q. Zheng, N-C. Yen, C. C. Tung, and H. H. Liu, "The Empirical Mode Decomposition and the Hilbert Spectrum for Nonlinear and Non-stationary Time Series Analysis," *Proceedings of the Royal Society*, **454**, 1998, pp. 903-995.

6. P. Racette, R. Lang, "Analysis of Radiometer Designs Based Upon Measurement Uncertainty," *Radio Science*, 40, RS5004, Sept. 2005.

7. P. Racette, U.S. Patent No. 8687742, Ensemble Detector: A device and method for collecting ensemble data sets, April 2014.