Adaptive Analysis in Medical Data Processing: The Hilbert-Huang Transform Challenges

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Abstract

Mathematical methods have historically assumed a central role in classical Signal Processing theory, carrying the robustness of the formal demonstration techniques to the methodologies, which start in some cases by empirical rules with good results in practice. Despite the solid Mathematical foundation, there are assumptions regarding the signal and the system itself that, if not considered, can lead to biased information, incomplete results or results without physical meaning. When faced with real data, usually we are dealing with the transient nature of the physical phenomena itself, and also to the finite span of captured data (which may be shorter than the longest time scale that describes the phenomena).

Signal stationarity and system linearity must be regarded as an exception instead of a rule in real data signal processing (in particular in biomedical data in which the non-stationarity property is highly present). Hence, a new paradigm of signal processing has emerged since the early nineties of the last century, changing the imposed *a priori* knowledge of the basis functions (*i.e.* sinusoidal functions or more recently wavelet functions). This adaptive analysis approach is based on the idea of choosing the methodology independently of the data to be processed.

To address the issue of non-linearity and non-stationarity, Huang and his coworkers in 1998 proposed a new approach to obtain the basis functions, extracted from the signal, in terms of a numerical procedure (shifting algorithm) known as Empirical Mode Decomposition (EMD)[1]. As result of this decomposition, the signal is separated into components (modes), producing a set of orthogonal basis functions (Implicit Mode Functions-IMF) derived from the signal in an adaptive manner. EMD is the first stage in the Hilbert-Huang Transform (HHT) methodology, obtained by applying the Hilbert transform to each IMF previously achieved by EMD. This second step is known by Hilbert Spectral Analysis (HSA), and the outcome of HHT is a time-frequency representation of the signal. HHT has been applied in different fields of science such as fluid dynamics in ocean engineering,

financial applications and system identification among many others [2][3]. By its own characteristics, biomedical signals are suited to HHT analysis and have been successfully applied to the study of a broad range of biomedical related problems. The EMD extension to 2 dimensions (BEMD) has been also used to image processing, in particular in the feature extraction to be used in Machine Learning algorithms [4].

In this talk, the HHT state-of-the-art will be presented, pointing the main steps in the recently proposed solutions for some identified drawbacks in the technique.The main goal is to increase the awareness of the Mathematical community for the open problems regarding the EMD decomposition. In order to illustrate the HHT performance, recent results from our group will be presented regarding the assessment of the homeostatic control in chronic dysfunction of the Autonomic Nervous System-ANS (as is the case in T2 diabetes rat model [5]) and also some examples of the clinical potential of using HHT in acute care management and clinical decision with patients.

Keywords: Adaptive Analysis, Hilbert-Huang Transform, Sympathovagal Balance.

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