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Editorial

The Empirical Mode Decomposition and the Hilbert-Huang Transform

Nii Attoh-Okine,[1] Kenneth Barner,[2] Daniel Bentil,[3] and Ray Zhang[4]

[1] *Department of Civil and Environmental Engineering, University of Delaware, Newark, DE 19716, USA*
[2] *Department of Electrical and Computer Engineering, University of Delaware, Newark, DE 19716, USA*
[3] *Departments of Mathematics and Statistics and Molecular Physiology Biophysics, The University of Vermont, Burlington, VT 05405, USA*
[4] *Civil Engineering Specialty, Division of Engineering, Colorado School of Mines, Golden, CO 80401, USA*

Correspondence should be addressed to Nii Attoh-Okine, okine@ce.udel.edu

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Data from natural phenomena are usually nonstationary due to their transient nature; also, the span of captured data may be shorter than the longest time scale that describes the phenomenon. In fact, since it is impossible or impractical to obtain infinite data points describing a phenomenon, all data are invariably short. To simplify processing and analysis, data stationarity is often assumed even though the condition may not be strictly satisfied. For instance, the stationarity assumption justifies traditional Fourier-based methods, which utilize a priori basis sets to globally decompose a signal. To directly address the processing of nonstationary and nonlinear signals, the Hilbert-Huang transform (HHT) has recently been developed. The HHT comprises two steps: empirical mode decomposition (EMD) and Hilbert spectral analysis (HSA). Unlike Fourier-based methods, the EMD decomposes a signal into its components adaptively without using a priori basis. The decomposition is based on the local time scale of the data. The adaptive nature of the process successfully decomposes nonlinear, nonstationary signals in the time domain. Moreover, the decomposition components, referred to as intrinsic mode functions (IMFs), are generally in good agreement with intuitive and physical signal interpretations. Moreover, the IMFs have well-defined instantaneous frequencies. Accordingly, the HSA Hilbert transforms the IMFs to generate a full energy-frequency-time plot (Hilbert spectrum), which gives the instantaneous energy and frequency content of the signal. The bidimensional empirical mode decomposition (BEMD) has recently been introduced as a 2D extension to the EMD. Thus, the EMD and BEMD are increasingly being employed to successfully address many contemporary signal processing applications.

Bidimensional empirical mode decomposition (BEMD) is an extension of the one-dimensional EMD applied to two-dimensional signals. Images are usually decomposed with BEMD using different interpolation methods to extract IMFs. An important aspect of the BEMD is the construction of envelopes when sifting for IMFs, which involves interpolation of scattered data formed by the extrema of the data. Three broad methods of scattered data interpolation are radial basis function methods, triangulation-based methods, and inverse distance weighted methods. In using any of these major methods, there are two approaches to data interpolation: global and local approaches. In the global approach, interpolated data are influenced by all data within the given domain, whereas in the local approach, interpolated values are influenced by data within a neighborhood of the interpolated points. Global methods tend to be computationally costlier than local methods due to the generation of larger coefficient matrices that can easily become highly ill-conditioned.

A number of issues have come up concerning empirical mode decomposition, including the following.

(1) Finding mathematical and physical meaning for IMFs, since EMD is essentially algorithmic in nature and lacks mathematical rigor.

(2) Determining the most appropriate interpolation scheme.

(3) Identifying criteria for stopping the sifting process.

(4) Handling of boundary or end effects during data interpolation.

Most success in EMD has been in 1D, however, one issue still persists in all these advancements: the physical significance of IMFs derived from the original data series or signal. A thorough understanding of the physical processes that generate data is required before any form of scientific explanation can be attributed to any particular IMF or group of IMFs. Even with this kind of thorough knowledge, there is still a level of ambiguity when trying to extract information from the IMFs that is directly relevant to the original signal and the physics of the underlying system. Before getting to the point where essential information can be extracted from the IMFs, there is a need to determine which IMFs are really relevant to the decomposition process and which carry the necessary information required to understand the underlying system, as EMD is a numerical procedure with possible numerical errors in the results.

BEMD has potential in image preprocessing in the area of edge detection. The first few IMFs in BEMD contain the highest spatial frequencies contained in the original image, so that separating out these first few IMFs can smooth out the image for further processing.

The purpose of this special issue is to address the following issues in both 1D and 2D empirical mode decompositions:

1. *theoretical analysis and understanding;*
2. *performance enhancements of the EMD;*
3. *single decomposition, monitoring, and analysis;*
4. *feature extraction;*
5. *fast and adaptive methods;*
6. *decomposition domain processing methods;*
7. *image analysis and segmentation;*
8. *texture representation and segmentation;*
9. *optimization;*
10. *signal fusion and interpolation;*
11. *signal processing applications in Engineering and Biomedical.*

This special issue contains 12 papers. Of these there are 5 theoretical papers. The article by J. F. Khan et al. introduced a novel contour-based method for detecting largely affine invariant interest or feature points. The main contribution of the paper is the selection of good discriminative feature points from relatively thinned edges. Repeatability rate, which evaluates the geometric stability under different transformation, was used as the performance criteria. L. Yan et al. developed a filtering approach to address the mode mixing problem caused by intermittency signal in EMD process. The authors first used wavelet denoising and then applied the EMD procedure. The results show that this filtering approach affectively avoids the mode mixing and retain useful information. S. McLaughin and Y. Kopsinis used double iterative sifting and high interpolation in the EMD procedure. It appears that this approach has the capability of improving the performance. Binwei Weng and Kenneth Barner developed a method for signal reconstruction. The proposed reconstruction algorithm gives the best estimate of a given signal in the minimum mean square error sense. The algorithm involves two steps: (a) formulation of linear weighting for the IMF, (b) bidirectional weighting. S. M. A. Bhuiyan et al. proposed a multiple hierarchical method for BEMD. In the approach, order statistics are used to get the upper and lower envelopes, where the filter size is derived from the data.

Two papers develop a hybrid approach between SVM, clustering, and EMD. N. Logothetis et al. initially used EMD procedure, and unsurpervised K-means clustering the IMF and exploiting the SVM on the extracted features. The authors tested their methodology on local field potential in monkey cortex for decoding its bistable structure-from-motion perception. Yu Yang et al. EMD is used as preprocessor for AR (autoregressive) analysis; SVM is then used to classifier the output.

There were few papers on the applications. H. Snoussi et al. performed a comparative analysis of EMD and complex empirical mode decomposition and bivariate empirical mode decomposition. The two new methods appear to be suitable to complex time series. The authors applied their methodology to posture analysis. Yanhui Liu et al. used the EMD procedure to develop a new technique—multimodal pressure flow method (MMPF) for assessment of cerebral autoregulation. The results obtained by the authors for the new methodology are applicable in engineering and biomedical applications. A. Bouchikhi et al. used the EMD in speech enhancement. The authors used two strategies: filtering and thresholding. The authors demonstrated that their propose approach performs better than wavelet applications. Olivier Adam used EMD as segmentation of killer whales vocalizations; the results were very favorable compared to the alternative methods. Finally, N. O. Attoh-Okine and A. Ayenu-Prah [1] used the BEMD to evaluate pavement image crack detection and classification. The work appears to have general application in structural health monitoring in civil infrastructure applications.

We sincerely hope that the diverse papers in this special issue will introduce various researchers, engineers, and students to this new emerging field. Although the EMD is at its infancy, the number of papers keeps increasing astronomically every year. Finally, we hope that more mathematicians will address some of the "mathematical and theoretical" limitations.

Nii Attoh-Okine
Kenneth Barner
Daniel Bentil
Ray Zhang

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