International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064

Signal Denoising Using EMD and Hilbert Transform and Performance Evaluation with K-S Test

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Abstract: ***The Hilbert-Huang transform (HHT) is viewed as a promising method to process the nonlinear and non-stationary signal. EMD method could decompose the signal into a number of IMFs among which are there several illusive components originate from the transform. Need to solve those illusive components. Here we introduced the approach of applying Kolmogorov-Smirnov test to the identification of illusive component in IMF components. The signal simulate test and faults signal analysis prove that this improved method to deal with the illusive components and mode confusion has an obvious advantage and reasonability.***

Keywords: faults signal analysis, empirical mode decomposition, kolmogorov-smirnov test, Improved Hilbert Huang transform

1. Introduction

The Hilbert-Huang transform (HHT) is viewed as a promising method to process the nonlinear and non-stationary signal. The key part of the method is the 'empirical mode decomposition' method with which any complicated data set can be decomposed into a finite and often small number of 'intrinsic mode functions' that admit well-behaved Hilbert transforms. EMD method could decompose the signal into a number of IMFs among which are there several illusive components originate from the transform, meanwhile, mode confusion is also need to solve. Here we introduced the approach of applying Kolmogorov-Smirnov test to the identification of illusive component in IMF components, and apply wavelet transform to eliminate mode confusion. This K-S test works on the null hypotheses that the cumulative density function (CDF) of a target distribution is statistically similar to the CDF of a reference distribution, proposes the similarity probability between the IMFs and the signal as the standard whether a IMF is illusive or not, and gets the aim to exclude the illusive component. The wavelet transform act as the preprocessor to decompose signal into various narrow-band signals, i.e., narrow-band filter, wavelet transform etc. to eliminate mode confusions which is generated by HHT method. Meanwhile combining these two approaches with HHT method, this can be called as improved Hilbert-Huang transform. The signal simulate test and faults signal analysis prove that this improved method to deal with the illusive components and mode confusion has an obvious advantage and reasonability.

2. Hilbert Huang Transform

HHT Known for the root for instantaneous frequency.HHT mainly performs two operations EMD (Empirical mode Decomposition) and IMF (Intrinsic Mode Function). EMD to decompose any multi-component signal into a set of IMFs, once the IMFs are obtained instantaneous frequency of each IMF can be determined by Hilbert transform. IMF is a new conception proposed by Huang who considers any multi-component signals are composed by some IMF.

In an IMF, the number of zero crossings and extrema must either equal or differ at most by one in whole data set, and the mean value of the envelope defined by the local maxima and the local minima is zero at every time point, so base on the conception of IMF, Huang built a method named empirical mode decomposition (EMD).

By means of obtaining a series of IMFs of any signals, the given signal $x(t)$ can be reconstructed by

$$X(t)=\sum_{n=1}^{N} c_n(t)+r_N(t) \qquad (1)$$

Where $c_n(t)$ is the IMF component and $r_N(t)$ is the residue.

After obtaining IMFs Hilbert Huang Transform can be applied to each IMF. Then original signal can be expressed has

$$X(t)=\mathrm{Re}(\sum_{n=1}^{N} a(t)e^{j\varphi(t)}) \qquad (2)$$

2.1. Input Signal, Noisy signal and Hilbert Huang Transform

Consider the input signal and input noisy signal which is a random signal and by using EMD decomposes signal to IMF.

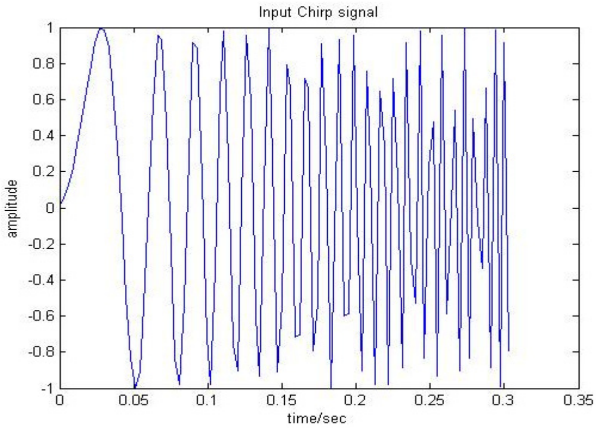


Figure 1: Input Chirp Signal

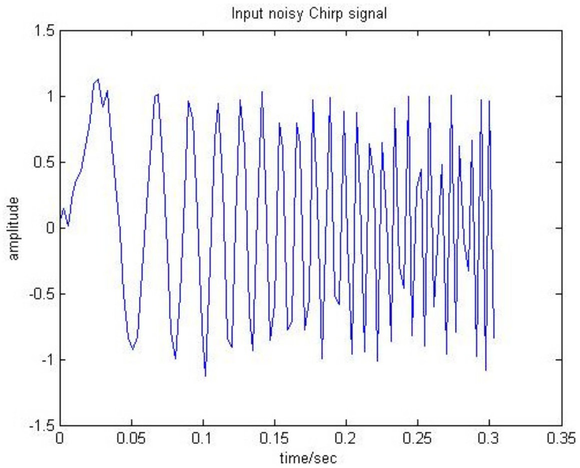


Figure 2: Input noisy chirp signal which random white Gaussian noise

The fault signal consists of chirp signal with noise; the EMD decomposes the given signal into IMFs as below

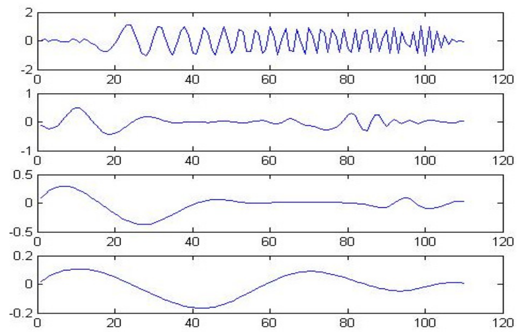


Figure 3: IMF of the given signal.

Then for the obtaining performing HHT we obtain illusive components and original signal in the HHT spectrum

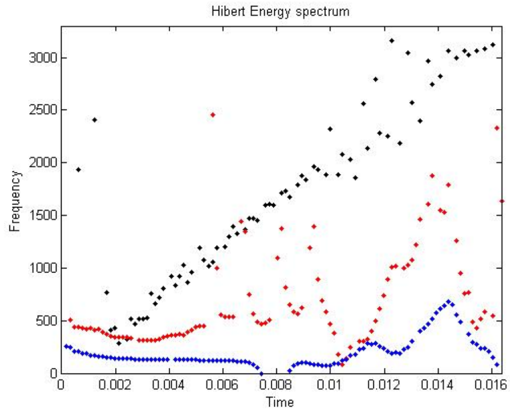


Figure 4: Hilbert Huang Spectrum

As shown in figure (4) the illusive component also appears in the lower frequency region. More disappointedly the original signal cannot exhibit clearly. EMD is a method based on local maxima and minima curve fitting. After every curve fitting, the signal must subtract the mean value of the envelope that roots in curve fitting, this step will bring new extrema. So lack-envelope and over-envelope will be easily appearing, and the illusive components will be brought by EMD. We aim this problem and propose the solution to eliminate this phenomenon.

3. Improved Hilbert Huang Transform Based on K-S Test

EMD method could decompose the signal into a number of IMFs among which are there several illusive components originate from the transform need to solve. Here we introduced the approach of applying Kolmogorov-Smirnov test to the identification of illusive component in IMF components.

K-s Test:

Kolmogorov-Smirnov test (K-S test) works on the null hypotheses that the cumulative density function of a target distribution is statistically similarly to that of a reference distribution. As to a N points time series y(n)={y1,y2,…yn}, its cumulative density function(CDF) is represented by:

$$E_i = {n(i)}/{N} \quad (3)$$

prob(D)= $Q_{ks}\left[\left(\sqrt{N_e} + 0.12 + \frac{0.11}{\sqrt{N_e}}\right) D\right]$ (4)

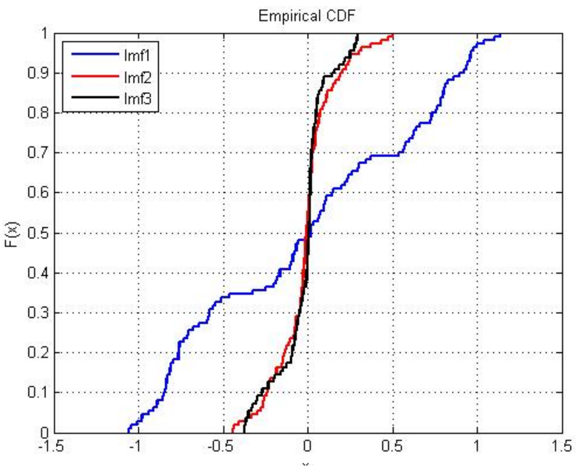


Figure 5: IMF density curve

Figure 4 shows the cumulative probability distribution curves of chirp signal as well as its first three IMF components. The cumulative probability distribution curves of the first IMF component is similar to that of chirp, however, the cumulative probability distribution curves of the second and the third IMF components are quite different from that of the original signal.

Based on the Eq.(4), we calculate the similarity probability of the first five IMF components of chirp respectively. As to chirp, only the similarity probability of the first IMF tends to 1, the others are 0. Where the similarity probability of the IMF component is 0 indicates the IMF component and the original signal have absolutely different probability distribution. Hence, these IMF components could be seen as the illusive component. When establishing Hilbert energy spectrum, we could obtain a more precise time-frequency spectrum by removing the illusive component in IMF components.

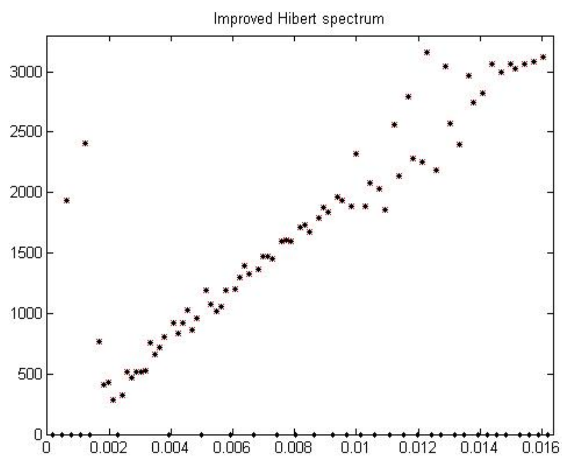
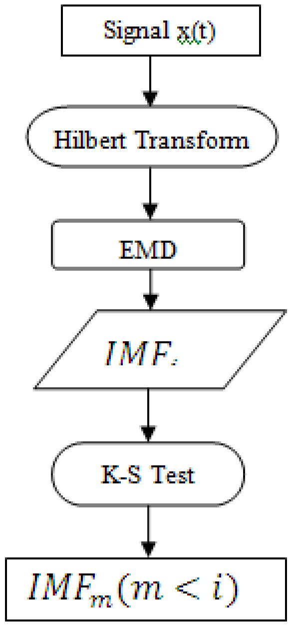


Figure 6: Hilbert Energy Spectrum without illusive components

4. Improved Hilbert Huang Transform

As introduced in above paragraphs, decompose the signal to individual IMFs using EMD, applying K-S test to recognize those illusive components which come from EMD, meanwhile, combining HHT method, this new method can be called improved Hilbert-Huang transform. The procedure of improved method is shown as follow:



The above figure (7) show the procedure for Improved Hilbert Huang Transform

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Chaitanya Kumar N received the B. Tech degrees in Electronics and communication engineering from Sree Venkateswara Institute of science and technology in 2011, respectively, and I am currently pursuing Master degree, M.Tech (CMS) in Sree Vidyanikethan Engineering College, Tirupati.