# Suya Han

**2017 Suya Han** **--A Novel Method for Separating Harmonic from Ultrasonic Echo Signals Using Improved Complete Ensemble Empirical Mode Decomposition with Adaptive Noise Algorithm**

**Purpose:** The performance of tissue imaging is improved by tissue harmonic imaging (THI)(组织谐波图像)to expand and enhance the range and level of clinical diagnosis for many diseases. The separation based on High-pass filtering (S\_HPF)（高通滤波器）is a commonly used method for extracting harmonic components from ultrasonic echo signals. However, the cutoff frequency, order and algorithm to realize a high-pass filter have a great influence on the separation accuracy（分离准确度）of harmonic signals.

**Methods:** In present study, a novel separation method (S\_CEEMDAN) based on the complete ensemble empirical mode decomposition(完整总体经验模式分解)with adaptive nois (CEEMDAN) algorithm（自适应信号算法）is proposed for adaptively separating harmonic components from ultrasonic echo signals. First, we calculate the ensemble size of CEEMDAN adaptively based on the added noise level, and draw a sum of intrinsic mode functions (IMFs) from the ultrasonic echo signals by CEEMDAN. Then,the spectrum of each IMF is computed and evaluated, and the IMFs containing both fundamental and harmonic components are further decomposed by using the CEEMDAN algorithm. This separation process is end until all of IMFs have been divided into either fundamental or harmonic categories. Finally, the corresponding fundamental and harmonic echo signals are yielded by accumulating separately these two categories.

**Conclusion:** In experiments, simulated ultrasonic echo signals with a center frequency of 3.5MHz are separated by the proposed S\_CEEMDAN method, and the results are compared with those processed by S\_HPF. The edge of the harmonic image by S\_CEEMDAN marginally（少量地）better defined than S\_HPF. The indices for the harmonic signals separated by S\_CEEMDAN and S\_HPF, respectively, are as follows: the center frequencies of 6.66MHz and 6.65 MHz, 3 dB bandwidths of 1.04 MHz and 1.05 MHz, 6 dB bandwidths of 1.59 MHz and 1.55 MHz, signal-to-noise ratios (SNRs) of 14.00 and 13.63, and image contrasts(对比)of 7.01 and 7.06. In conclusion, due to good adaptive characteristics, and lower reconstruction errors(重构误差), the proposed S\_CEEMD method is superior to S\_HPF in the performance of spectral accuracy and harmonic imaging. This method could be potentially alternative to the current method for the ultrasonic harmonic separation.