HHT-Based Time-Frequency Analysis in Voice Rehabilitation

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Abstract: - This paper discusses the time-frequency characteristics of recorded human voice changes before and after rehabilitation by using Hilbert-Huang Transformation (HHT) analysis. In addition, the objective is to determine how the HHT time-frequency distributions of recorded human voice changes before and after rehabilitation and then to identify the physical basis for each type of change seen in the HHT-based concepts. The basic goal is to devise a distribution that represents the intrinsic mode functions of a voice rehabilitation signal simultaneously in time and frequency. We explain the differences in the intrinsic mode functions (IMFs) and instantaneous frequencies (IFs) before and after voice rehabilitation.

Key-Words:- voice rehabilitation, HHT-based content, time-frequency distribution, intrinsic mode functions, instantaneous frequencies, amplitude.

1 Introduction

Time-frequency analysis scheme assist people to understand the concept of signals. Fourier transform (FT), wavelet transform (WT), and Hilbert-Huang transformation (HHT) are the 3 major approaches used in signal analysis [1-3]. HHT is a good method for analyzing non-linear and non-stationary signals, such as those associated with wind, earthquakes, electrocardiographs (ECGs), electroencephalograms (EEGs), and voice rehabilitation. This method can also used to describe the local features of dynamic signals, and illustrate the energy-frequency-time distribution of these signals. The 2 principal steps employed in HHT are empirical mode decomposition (EMD) and Hilbert spectral analysis, EMD is used to decompose local signals to finite data sets, which are referred to as intrinsic mode functions (IMFs), and Hilbert transforms (HTs) are used in conjunction with the obtained IMFs to determine the instantaneous frequencies (IFs), Hilbert marginal frequencies (HMFs), and Hilbert energy spectra of the local time signals. A number of studies have been performed to elucidate various aspects of HHT-based signal analysis. Hu et al., [4] describe a vibration signal analysis method based on HHT. The authors evaluate the effectiveness of HHT for non-stationary vibration signal analysis, and describe systematic tests conducted on a rotor test system. Hu et al., [5] redefined the redefinition of the instantaneous energy density level of HHT and proposed a modified pitch period detection algorithm. The authors used this algorithm to estimate the pitch of normal and abnormal voices. We have previously discussed the time-frequency characteristics of the FP1 EEG signals recorded for normal and alcoholic observers watching a single picture and 2 different pictures [6-7]. The discussions of chaos-based encryption mechanisms and mobile telemedicine systems have been scrupulously studied in our earlier work [8]-[16].

In this article, we presented to be understandable to the differences of intrinsic mode functions of before and after voice rehabilitation signals, respectively.

2.HHT-based Time Frequency Analysis

In the HHT temporal frequency-energy-time signal analysis technique, EMD is used to perform IMFs decomposition, and HT is used to obtain the IFs, HMFs, and Hilbert energy spectra.

The following procedure is employed for analyzing the IMF using EMD:
Step 1: initially assume \( r_o = x(t) \) and \( i=1 \);
Step 2: analyze the ith IMF;
(a) initially assume \( h_{ik-1} = r_i, k=1 \);
(b) analyze the local maximum and minimum for \( h_{ik-1} \);
(c) construct the upper-limit and lower-limit envelope for \( h_{ik-1} \) by performing additional sampling;
(d) calculate the-mean \( m_{ik-1} \) of the upper-limit and lower-limit envelope for \( h_{ik-1} \);
(e) \( h_k = h_{ik-1} - m_{ik-1} \);
(f) if \( h_k \) is the IMF, then \( IMF_i = h_k \) ; alternatively, refer to step (b) and consider \( k = k+1 \);

Step 3: define \( r_{i+1} = r_i - IMF_i \);
Step 4: if \( r_{i+1} \) has at least 2 extreme values, refer to step 2 or consider that the analysis procedure is complete and that \( r_{i+1} \) is the residual signal;

In such cases, IMF is defined by 2 conditions:
Condition 1: The difference between the crossing with zero and the local extreme value of the entire data shall be equal or the difference with 1.
Condition 2: The mean of any point is the average of the local maximum and minimum envelope.

In addition, the HHT-based time-frequency analysis scheme is performed on the basis of 4 assumptions:
Assumption 1: At least 2 extreme value for the signals, i.e. maximum and minimum values, are present.
Assumption 2: The scale size of the characteristic time is selected according to the extreme values and the temporal interval.
Assumption 3: If that the data to be analyzed have no extreme values but contain identifiable points that can be expressed as extreme points of single or multiple analyses, and accompany with an increase in the number of analyses, the maximum/minimum points gain significance.
Assumption 4: The final result should be the sum of the above stated composition.

Thus, the voice rehabilitation signal can be defined as function \( x(t) \), and function \( x(t) \) can be expressed as the following empirical mode function to analyzes the IMF.

\[
x(t) = \sum_{j=1}^{n} IMF_j(t) + r(t)
\]

where, \( IMF_j(t) \): the \( j \)th IMF \( r(t) \): attribution function(residual)

Then

\[
z(t) = x(t) + jy(t) = x(t) + jHT\{x(t)\} = a(t)e^{j\theta(t)}
\]

\[HT\{\cdot\}\] :Hilbert Transformation
\[a(t) = \sqrt{x^2(t) + y^2(t)}
\]
\[\theta(t) = \arctan\left(\frac{y(t)}{x(t)}\right)
\]

Thus, the IF of a voice rehabilitation signal can be analyzed using the following equation:

\[
f = \frac{1}{2\pi} \frac{d\theta(t)}{dt}
\]
Using the HHT-based time-frequency analysis technique, the time-frequency characteristic vector of the voice rehabilitation signal can be acquired, and the frequency characteristics, amplitude characteristics, time-dependent temporal-spatial frequency correlation, and correlation of the voice rehabilitation signal to the clinical characteristics can be analyzed. Furthermore, this approach can allow determination of statistically common and abnormal points, generalization of a standard by comparison with a normal sample, augmentation the efficiency of observation, and analysis of the voice rehabilitation signal.

3. Analysis Results
When the physiological structures of the larynx voice of a human do not meet the basic needs of his voice, the voice disorders is caused. The most voice disorders can be improved by using the voice rehabilitation method. In acoustics scheme, the parameters of the fundamental frequency, jitter, shimmer, and harmonic-to-noise-ration are used to track the variations of patients’ voice. In the paper, we used HHT-based time frequency concepts of the voice rehabilitation signal to discuss the variations of patients’ voice. Figure 1 (a) shown the voice with hoarseness and painfull of throat. The audio signal is before the voice rehabilitation. Figure 1 (b) shown the audio signal is after the voice rehabilitation. The voice with hoarseness and painful of throat has been improved. Figure 2 presented the IMFs of the voice rehabilitation signal. We observed the variations of amplitudes-time distributions of the signal of the former rehabilitation is large than the signals after rehabilitation.

4. Conclusion
HHT-based timefrequency analysis in the voice rehabilitation signal is an interesting research topics. We decompose voice rehabilitation signal into several IMFs to understand the characteristic of the voice rehabilitation signal by using MD method. We presented the concept of the IMFs of the voice rehabilitation signal. We will discuss the instantaneous frequencies, Hilbert marginal frequencies, and Hilbert energy spectra of the voice rehabilitation signal in the next stage.

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References:
Figure 2 IMFs of recorded human voice changes before and after rehabilitation


