CHAPTER 6
HILBERT HUANG TRANSFORMATION FOR VEGETATION SEGMENTATION

6.1 INTRODUCTION

This chapter presents the implementation of Hilbert-Huang transform for segmenting the Landsat image and finding out the area of vegetation.

6.2 EMPIRICAL MODE DECOMPOSITION (EMD)

6.2.1 Processing intensity values row wise

A signal can be analyzed in details for its frequency, amplitude and phase contents by using EMD followed by Hilbert Transform (HT). The EMD produces the mono components called intrinsic mode functions (IMFs) from the original signal. In a given frame of signal, there can be many IMFs. Each IMF will contain a waveform of different amplitude. Hilbert Transform is applied on an IMF to obtain, instantaneous frequency (IF) and instantaneous amplitude (IA). It is mandatory that a signal be symmetric regarding the local zero mean, and should contain same number of extreme and zero crossings.

The steps involved in EMD of a signal X(t) with multispectrum into a set of IMFs are as follows.
**Step 1:** All local maxima of X(t) are identified. The points are connected using a cubic spline. The interpolated curve is obtained. The upper line is called the upper envelope (Maximum_envelope).

**Step 2:** All local minima of X(t) are identified. The points are connected using a cubic spline. The lower line is called the lower envelope (Minimum_envelope) obtained by cubic spline.

**Step 3:** The average is computed by:

\[ M = \frac{(a + b)}{2} \]  \hspace{1cm} (6.1)

Where \( a = \text{Maximum_envelope} \) and \( b = \text{Minimum_envelope} \).

Figure 6.1 presents the decomposition process of the first row intensity values (blue color) of the NIR vegetation image. The upper envelope (green color), lower envelope (red color), average values (black color) are shown. This plot is obtained to get the first IMF. Subsequent iterations will give additional IMF.

**Step 4:** A new signal is obtained using the following equation:

\[ h_{11}(t) = X(t) - M_{11}(t) \]  \hspace{1cm} (6.2)

Where, \( h_{11}(t) \) is called first IMF. Subsequent IMF’s had to be found if there are some overshoots and undershoots in the IMF. Hence, the ‘envelope mean’ differs from the true ‘local mean’ and \( h_{11}(t) \) becomes asymmetric.
In order to find the additional IMF’s, \( h_{11}(t) \) is taken as the new signal. After \( n^{th} \) iteration, the equation (6.3) is used.

\[
h_{1n}(t) = h_{1(n-1)}(t) - M_{1n}(t)
\]  

(6.3)

Where, \( M_{1n}(t) \) is the mean envelope after the \( n^{th} \) iteration and \( h_{1(n-1)}(t) \) is the difference between the signal and the mean envelope at the \((k-1)^{th}\) iteration.

**Step 5:** Coarse to fine (C2F) is calculated using equation (6.4).

\[
C2F_i = IMF_n
\]  

(6.4)

Where, \( IMF_n \) = final IMF obtained

\[
C2F_2 = IMF_n + IMF_{(n-1)}
\]  

(6.5)

Similarly,

\[
C2F_n = IMF_n + IMF_{(n-1)} + \ldots + IMF_1
\]  

(6.6)

Where \( C2F_n \) is the original signal.

**Step 6:** Fine to coarse (F2C) is calculated using equation (6.7).

\[
F2C_i = IMF_i
\]  

(6.7)

\[
F2C_2 = IMF_i + IMF_2
\]  

(6.8)

\[
F2C_n = IMF_i + IMF_2 + \ldots + IMF_n
\]  

(6.9)

Where, \( F2C_n \) is the original signal.

**Step 7:** Hilbert transform is applied for each IMF and analytical signal is obtained.

A complex signal is obtained from each IMF:
Step 8: Instantaneous frequencies are obtained from analytical signal using

\[ IF = \frac{0.5 \times (\text{angle}(X(t+1) \times \text{conj}(X(t-1))) + \pi)}{2 \times \pi} \]  

(6.11)

Step 9: Instantaneous amplitudes are obtained from the analytical signal using the following

\[ IA = \sqrt{(\text{real}(\text{IMF})^2 + \text{imag}(\text{IMF})^2} \]  

(6.12)

6.2.2 Feature extraction from HHT

Twelve features are extracted from each IF and IA. The features are mean, standard deviation, norm, maximum and minimum of IF. Similarly mean, standard deviation, norm, maximum and minimum of IA and energy of F2C and C2F waveforms of an IMF.

\[ V_1 = \frac{1}{d} \sum (\text{IF}) \]  

(6.13)

Where \( d \) = Samples in a frame and \( V_1 \) = Mean value of Instantaneous Frequency.

\[ V_2 = \frac{1}{d} \sum (\text{IF} - V_1) \]  

(6.14)

Where \( V_2 \) = Standard Deviation of Instantaneous Frequency.

\[ V_3 = \text{maximum} (\text{IF}) \]  

(6.15)

\[ V_4 = \text{minimum} (\text{IF}) \]  

(6.16)

\[ V_5 = \text{norm}(\text{IF})^2 \]  

(6.17)
Where $V_5 =$ Energy value of frequency.

\[
V_6 = \frac{1}{d} \sum (IA) \quad (6.18)
\]
\[
V_7 = \frac{1}{d} \sum (IA-V_6) \quad (6.19)
\]

Where $V_7 =$ Standard Deviation of Instantaneous amplitude

\[
V_8 = \text{maximum (IA)} \quad (6.20)
\]
\[
V_9 = \text{minimum (IA)} \quad (6.21)
\]
\[
V_{10} = \text{norm(IA)}^2 \quad (6.22)
\]

Where $V_{10} =$ Energy value of Amplitude.

\[
V_{11} = \sum \log_2 (\text{abs}(F2C))^2 \quad (6.23)
\]

Where $V_{11} =$ Log 2 value of F2C

\[
V_{12} = \sum \log_2 (\text{abs}(C2F))^2 \quad (6.24)
\]

Where $V_{12} =$ Log 2 value of C2F.

Figure 6.2 shows the EMD process. In the sample signal considered, only one instantaneous mode function is present. A flat residue signal is also presented. This plot is only for 504 samples (intensity values of the first row). This will be repeated for the remaining length of the signal (intensity values). Figure 6.3 shows the extraction of different signals present from the fine level to coarse level. Similarly, Figure 6.4 shows the extraction of different signals present from the coarse level to fine level.
Figure 6.5 shows the maximum of the mean of the amplitude between 2\textsuperscript{nd} to 5\textsuperscript{th} frame. Figure 6.6 shows maximum standard deviation at 2\textsuperscript{nd}, 3\textsuperscript{rd}, 7\textsuperscript{th} frames. Figure 6.7 shows maximum Norm at 2\textsuperscript{nd}, 12\textsuperscript{th}, 16\textsuperscript{th}, 19\textsuperscript{th} frames. Figure 6.8 shows maximum standard deviation at 2\textsuperscript{nd}, 4\textsuperscript{th}, 6\textsuperscript{th}, 7\textsuperscript{th}, 10\textsuperscript{th}, 18\textsuperscript{th}, 19\textsuperscript{th} frames. Figure 6.9 shows maximum of the minimum at 2\textsuperscript{nd}, 4\textsuperscript{th}, 6\textsuperscript{th}, 7\textsuperscript{th}, 10\textsuperscript{th}, 18\textsuperscript{th}, 19\textsuperscript{th} frames (similar to that of Figure 6.8).

6.2.3 Processing intensity values column wise

All the steps adopted for processing intensity values row wise are also adopted for column wise processing. The peak values obtained in each plot are identified and a matrix plot is generated to identify the area of the vegetation.

Figure 6.10 shows the maximum of the mean of the amplitude between 2\textsuperscript{nd} to 5\textsuperscript{th} frame. Figure 6.11 shows maximum standard deviation at 2\textsuperscript{nd}, 3\textsuperscript{rd}, 7\textsuperscript{th} frames. Figure 6.12 shows maximum Norm at 2\textsuperscript{nd}, 12\textsuperscript{th}, 16\textsuperscript{th}, 19\textsuperscript{th} frames. Figure 6.13 shows maximum standard deviation at 2\textsuperscript{nd}, 4\textsuperscript{th}, 6\textsuperscript{th}, 7\textsuperscript{th}, 10\textsuperscript{th}, 18\textsuperscript{th}, 19\textsuperscript{th} frames. Figure 6.14 shows maximum of the minimum at 2\textsuperscript{nd}, 4\textsuperscript{th}, 6\textsuperscript{th}, 7\textsuperscript{th}, 10\textsuperscript{th}, 18\textsuperscript{th}, 19\textsuperscript{th} frames (similar to that of Figure 6.13). Figure 6.15 shows the segmented landsat image.
6.3 SUMMARY

This chapter presents the implementation of Hilbert-Huang transform for segmentation of landsat image to find the presence of vegetation. The frame length used to choose number of pixels in a row or column, for processing contributes to the accuracy of segmentation. Chapter 7 presents conclusions and future scope of the work.
Fig. 6.1 First row of the NIR image intensity values
Fig. 6.2 Empirical mode decomposition
Fig. 6.3 Fine to coarse signals
Fig. 6.4 Coarse to fine signals
Fig. 6.5 Mean of IA
Fig. 6.6 Standard deviation of instantaneous amplitude
Fig. 6.7 Norm of instantaneous amplitude
Fig. 6.8 Maximum of instantaneous amplitude
Fig. 6.9 Minimum of the instantaneous amplitudes
Fig. 6.10 Mean of IA
Fig. 6.11 Standard deviation of IA
Fig. 6.12 Norm of IA
Fig. 6.13 Maximum of IA
Fig. 6.14 Minimum of the IA
Fig. 6.15 Landsat image segmented using HHT