Analyses of Instantaneous Frequencies of Sharp I, and II Electroencephalogram Waves for Epilepsy

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Abstract: - In this chapter, we analyse the HHT-based characteristics of the instantaneous frequencies (IFs) of the clinical normal, sharp I, and II electroencephalogram (EEG) signals recorded from epilepsy subjects. In addition, we discuss the frequency-energy distributions of the intrinsic mode functions (IMFs), the mean, standard deviation, and maximum, and minimum frequencies of the IFs for the clinical normal, sharp I, and II, EEG signals recorded from epilepsy subjects. The ratios of the energy for several IMFs of the normal, sharp I, and II EEG waves in the δ band to their corresponding total refereed energy were analyzed, respectively.

Key-Words: - HHT-based characteristics, instantaneous frequencies, frequency-energy distributions, normal, sharp I, and II EEG signals, epilepsy.

1 Introduction

Huang *et al.*, [1] expanded on the basic concept of the Hilbert transform (HT) to analyze non-linear and nonstationary geophysical time series. This method, called the Hilbert-Huang transform (HHT), is a combination of empirical mode decomposition (EMD) and Hilbert spectral (HS) analysis. EMD is an iterative, data-driven technique that uses the characteristics of signals to adaptively decompose them to several intrinsic mode functions (IMFs). See [1-11] for an explanation of the fundamentals, mathematical derivation of HHT, as well as the difference between Fourier, and wavelet analyse. Lin *et al.* [10] discussed the application of HHT-based time-frequency analysis methods to EEG signals with explanations for alcoholic [5, 6]. Rutkowski *et al*. [12] discussed a novel approach to separate muscular interference from brain electrical activity observed in the form of EEG. All IMFs extracted from analyzed EEG signals were transformed into the Fourier domain. Cheng *et al.* [13] used EMD to analyze steady-state visually evoked potentials (SSVEP) in EEGs, and found that the sixth IMF reflected the features of the attention-to-rest transition response. The studies examine the application of HHT integrated with numerous methods for analyzing biomedical signal frequency characteristics.

2. Statistical characteristics of the instantaneous frequencies of normal, sharp I, and II EEG waves

The HHT-based characteristics of the instantaneous frequencies (IFs) of the clinical normal, sharp I, and II electroencephalogram (EEG) signals recorded from epilepsy subjects. Tables I shows the statistical characteristics of the IFs for the normal, sharp I, and II EEG waves, respectively. The mean frequencies of the IF1 for normal, sharp I, and II were 49, 42, and 44 Hz, respectively. The mean frequencies of the IF2 for normal, sharp I, and II were 21, 16, and 12 Hz, respectively. The mean frequencies of the IF3 for normal, sharp I, and II were 10, 4, and 6 Hz, respectively. The mean frequencies of the IF4 for normal, sharp I, and II were 3, 1, and 3 Hz, respectively. With increase in the intrinsic mode function (IMF), the mean, standard deviation, and maximum and minimum frequencies of the IFs decreased. Tables II shows the energies of the various frequency bands of the IFs for the normal, sharp I, and II EEG waves, respectively. The refereed wave band higher than 5% of the refereed total energy is marked in red. The ratio of the energy of the sharp I EEG waves for IMF3 to its refereed total energy in the δ band was 13.37%. The refereed total energy of sharp I EEG waves was defined as following:

$$E_r(t) = \sum_{i=1}^{L} IMF_i^2(t) + RF^2(t) \quad (1)$$

$IMF_i(t)$: the *ith* IMF.of sharp I EEG wave.

RF(t): the residual functions of sharp I EEG wave.

The ratios of the energy of the normal, sharp I, and II EEG waves for IMF4 to their corresponding refereed total energy in the δ band were 32.95%, 33.12%, and 22.16%, respectively. The ratios of the energy of the normal, and sharp II, EEG waves for IMF5 to their corresponding refereed total energy in the δ band were 34.83%, and 5.00%, , respectively. The ratios of the energy of the sharp I, and II EEG waves for the residual function to their corresponding total refereed energy in the δ band were 11.69%, and 7.19%, respectively. The ratios of the energy of the sharp I, and II EEG waves for the IMF2 to their corresponding refereed total energy in the θband were 12.20%, and 8.47%, respectively. The ratios of the energy of the normal, sharp I, and II EEG waves for the IMF3 to their corresponding refereed total energy in the θband were 6.49%, 20.57%, and 26.03%, respectively. The ratios of the energy of the normal EEG waves for the IMF4 to their corresponding refereed total energy in the θband were 7.14%. The ratios of the energy of the sharp II EEG waves for the IMF2 to their corresponding refereed total energy in theα band were 6.63%. The ratios of the energy of the sharp II EEG waves for the IMF2 to their corresponding refereed total energy in theβband were 18.22%.

3. Conclusion

In the paper, we discussed the frequency-energy distributions of the intrinsic mode functions (IMFs) for the clinical normal, sharp I, and II, EEG signals recorded from epilepsy subjects. Future studies can further develop and examine more HHT frequency characteristic analysis methods for the clinical normal, sharp I, II, and III EEG signals recorded from epilepsy subjects. We enable greater understanding of the HHT frequency characteristics of these signals, and apply to mobile telemedicine [14-20].

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Tables I The statistical characteristics of the IFs for the normal, sharp I, and II EEG waves, respectively.

	IFs	min (Hz)	max (Hz)	mean (Hz)	std (Hz)
normal	IF1	-112.0891	124.4003	49.0421	28.2880
sharp I		-121.4965	116.4044	42.0412	34.3779
sharp II		-104.3366	121.4019	44.9352	26.7715
normal	IF2	-75.6276	63.2203	21.9630	11.5735
sharp I		-41.3318	106.7026	16.2507	12.5569
sharp II		-23.8190	38.6310	12.8831	10.0738
normal	IF3	-26.8094	22.0467	10.1031	4.8333
sharp I		-43.7631	42.8431	4.8905	7.5295
sharp II		-19.5439	39.2902	6.9442	5.2194
normal	IF4	0.5207	7.4843	3.9353	1.9067
sharp I		0.2385	3.7575	1.9466	0.7375
sharp II		-6.6188	20.4230	3.0002	3.2011
normal	IF5	0.0540	5.5358	2.0450	0.5564
sharp I		-	-	-	-
sharp II		-1.3335	48.8465	2.9912	4.9041
normal	IF	0.0110	7.8437	0.9250	0.7762
sharp I	residual function	-0.1608	8.6064	0.9191	0.6732
sharp II		-6.7407	8.3760	0.9989	0.8932

Tables II The energies of the various frequency bands of the IFs for the normal, sharp I, and II EEG waves, respectively.

	IFs	ζ wave (μv^2)	δ wave (μv^2)	θ wave (μv^2)	α wave (μv^2)	β wave (μv^2)	γ wave (μv^2)
normal	IF1	0.5904	0	0	0	73.0068	220.2037
		0%	0%	0%	0%	0.33%	0.99%
sharp I		40.0172	0	1.9890	0.9628	810.3570	354.9458
		0.03%	0%	0%	0%	0.66%	0.29%
sharp II		0.3180	0.0609	0.3991	17.9767	683.2514	520.5802
		0%	0%	0%	0.06%	2.22%	1.69%
normal	IF2	1.4273	0.0070	86.9518	367.7425	827.555	63.5502
		0.01%	0%	0.39%	1.66%	3.74%	0.29%
sharp I		3	14	15049	4689	818	31
		0%	0.01%	12.20%	3.8%	0.66%	0.03%
sharp II		1.8	256.5	2609.5	2041.7	5611.9	0.8
		0.01%	0.83%	8.47%	6.63%	18.22%	0.2%
normal	IF3	2.4	123.6	1436.6	377.3	313.5	0
		0.01%	0.56%	6.49%	1.7%	1.42%	0%
sharp I		13	16491	25370	380	509	0
		0.01%	13.37%	20.57%	0.31%	0.41%	0%
sharp II		1.3	35.5	8018.5	30.2	6.7	1
		0%	0.12%	26.03%	0.10%	0.02%	0%
normal	IF4	0	7296.9	1580.9	0	0	0
		0%	32.95%	7.14%	0%	0%	0%
sharp I		663	40847	0	0	0	0
		0.54%	33.12%	0%	0%	0%	0%
sharp II		61.9	6825.5	54.4	12	0.1	0

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		0.2%	22.16%	0.18%	0%	0%	0%
normal	IF5	3.7	7714.7	8.5	0	0	0
		0.02%	34.83%	0.04%	0%	0%	0%
sharp I		-	-	-	-	-	-
		-	-	-	-	-	-
sharp II		25.8	1541.6	11.2	6.6	16	4.7
		0.08%	5%	0.04%	0.02%	0.05%	0.02%
normal	IF residual function	676.4549	924.0803	48.3155	0	0	0
		3.05%	4.17%	0.02%	0%	0%	0%
sharp I		2356	14421	237	243	0	0
		1.91%	11.69%	0.19%	0.20%	0%	0%
sharp II		117.4	2216.5	0	80.7	0	0
		0.38%	7.19%	0%	0.26%	0%	0%

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