Suparerk Janjarasjitt, 2014. Examination of the wavelet-based approach for measuring self-similarity of epileptic electroencephalogram data. *Journal of Zhejiang University-SCIENCE C (Computers & Electronics)*, **15**(12):1147-1153. [doi:10.1631/jzus.C1400126]

JZUS C (Comput & Electron)

# Examination of the wavelet-based approach for measuring self-similarity of epileptic electroencephalogram data

**Key words:** Self-similarity, Power-law behavior, Wavelet analysis, Electroencephalogram, Epilepsy, Seizure

Corresponding author: Suparerk Janjarasjitt
E-mail: suparerk.j@ubu.ac.th

# Introduction

- The mathematical concept of a fractal is commonly associated with irregular objects that exhibiting a property called self-similarity or scale-invariance (Mandelbrot, 1982; Goldberger, 2006)
- An important class of statistical scale-invariant or self-similar random processes is the 1/*f* process (Wornell, 1995)
- In general, models of 1/*f* process are represented using a frequency domain characterization
- The dynamics of 1/*f* process exhibit power-law behavior (Watters, 1998) and can be characterized in the frequency domain .
- Wornell (1993; 1995) developed a wavelet-based representation for 1/*f* process
- In this study, a computational method based on a wavelet-based representation of 1/*f* process is used to estimate the spectral exponent which characterizes the self-similarity of a signal
- The application of the wavelet-based approach to epileptic EEG data analysis is demonstrated

IZUS C (Comput & Electron)

# Wavelet-based self-similarity measure

- According to the theorem developed by Wornell (1993), the spectral exponent of a 1/*f* process can be determined from a linear relationship between $\log_2 \mathrm{var}(d_{m,n})$ and the level *m*

- The wavelet-based approach for estimating the spectral exponents can be performed in the following steps:

    1. Normalized a signal

    2. Decompose the normalized signal into *M* levels using the wavelet-basis expansions to obtain the wavelet coefficients $d_{m,n}$ where $m=1,2,\ldots,M$

    3. Compute the variance of wavelet coefficient corresponding to each level *m*

    4. Compute the logarithm to base 2 of the corresponding variances of wavelet coefficients

    5. Estimate the slope of the $\log_2 \mathrm{var}(d_{m,n})$-*m* graph to obtain the spectral exponent

JZUS C (Comput & Electron)

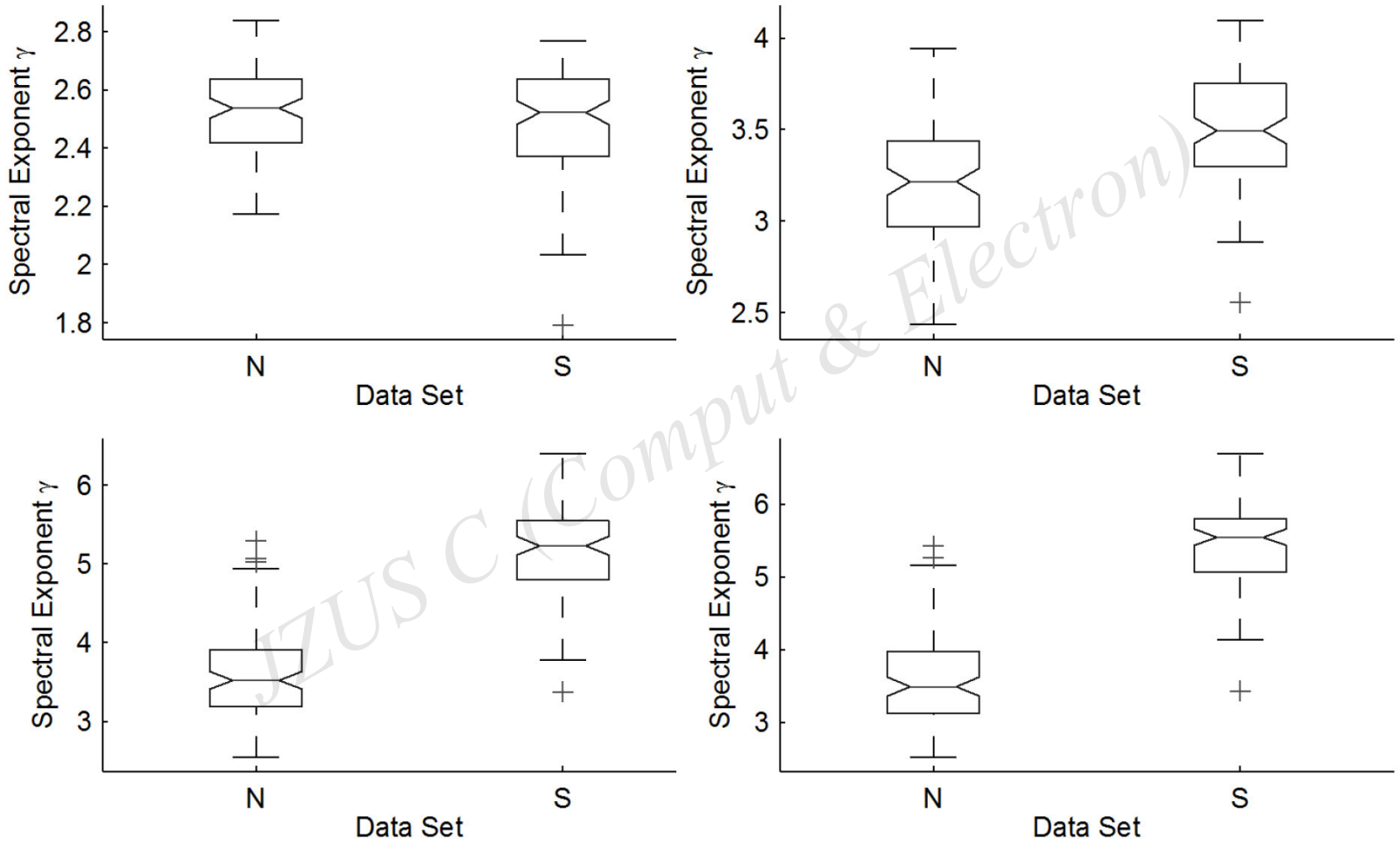
# Results

| Wavelet bases | $\log_2$ var | |
|---|---|---|
| | N | S |
| Db1 | $2.5261 \pm 0.1396$ | $2.4979 \pm 0.1767$ |
| Db2 | $3.2260 \pm 0.3125$ | $3.5166 \pm 0.3122$ |
| Db10 | $3.6292 \pm 0.6003$ | $5.1918 \pm 0.5559$ |
| Db30 | $3.6121 \pm 0.6667$ | $5.4487 \pm 0.5886$ |

JZUS C (Comput & Electron)

**The statistical values (mean±standard deviation) of the intracranial EEG data**

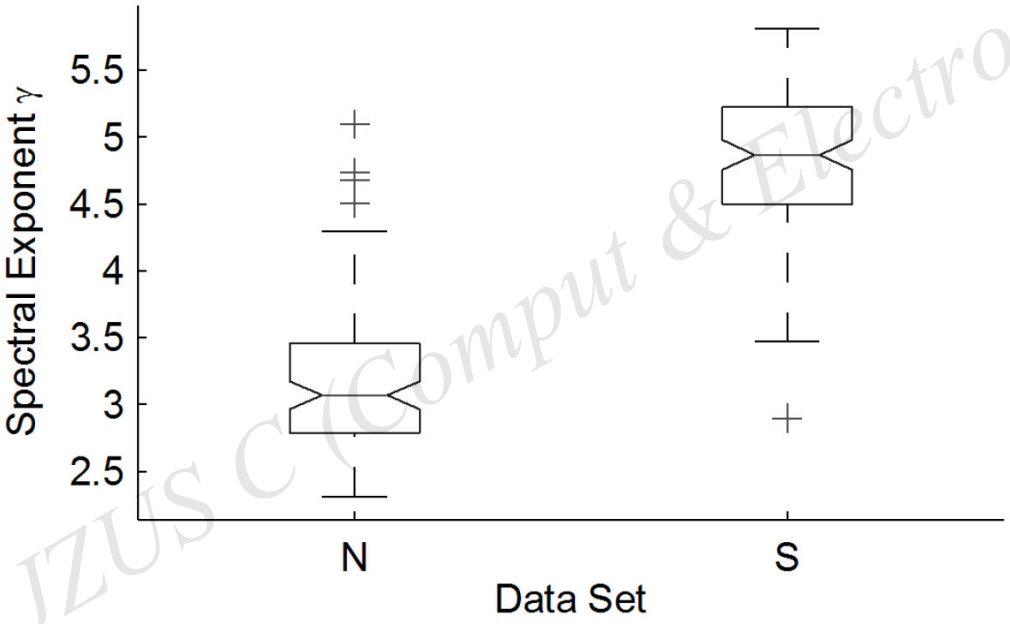
# Results




JZUS C (Comput & Electron)

Comparison of the spectral exponents of the intracranial EEG data sets N and S using Daubechies wavelet bases Db1 (a), Db2 (b), Db10 (c), and Db30 (d)

# Results




JZUS C (Comput & Electron)

Comparison of the spectral exponents of the intracranial EEG data sets N and S using the power spectrum method

# Conclusions

- The computational results show that an approach based on a wavelet-based representation of 1/*f* process can be used successfully to estimate the spectral exponent which characterizes self-similarity
- The spectral exponents of the intracranial EEG signals estimated using the wavelet-based approach were generally comparable to those estimated using the power spectrum method
- However, the wavelet transform method is naturally suited for manipulating self-similar or scale-invariant signals
- The computational results suggest that intracranial EEG signals obtained during epileptic seizure activity tend to be more self-similar than those obtained during non-seizure periods
- A significant difference between the spectral exponents obtained during epileptic seizure activity and those obtained during non-seizure periods can be observed
- This is sufficient to reveal the characteristics of the underlying neuronal dynamics of the brain corresponding to different pathological states, i.e., ictal and interictal states

JZUSC (Comput & Electron)