

## Adaptive Data Analysis Methods with Some Biomedical Applications

Norden E. Huang  
Research Center for Adaptive Data Analysis  
National Central University

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## Data Processing and Data Analysis

- ✦ Processing [proces < L. Processus < pp of Procedere = Proceed: *pro-* forward + *cedere*, to go] : A particular method of doing something.
- ✦ Data Processing >>>> Mathematically meaningful parameters
- ✦ Analysis [Gr. *ana*, up, throughout + *lysis*, a loosing] : A separating of any whole into its parts, especially with an examination of the parts to find out their nature, proportion, function, interrelationship etc.
- ✦ Data Analysis >>>> Physical understandings

## Scientific Activities

Collecting, analyzing, synthesizing, and theorizing are the core of scientific activities.

Data are our only connection to reality; they are also what separate science from philosophy.

Therefore, data analysis is a key link in this continuous loop.

## Some New Approaches for Data Analysis

- ✦ Categorization and classification
- ✦ Quantification of complexity
- ✦ Time-Frequency Analysis with Adaptive Basis.

## 1. Categorization or Classification

The work by Linnaeus is the key to the progress in biological sciences.

複雜數據分類

### 基於重複模式的 複雜數據分類

Quantitatively categorize complex signals based on the occurrences of repetitive patterns:  
**Based on the work of Albert Yang (VGHTPE) and C. K Peng (Harvard, Medical School)**

Yang *et al.* Phys Rev Lett 2003; 90:108103; Physica A 2003:329:473-83;  
J Comput Biol 2005; 12:1103  
Peng *et al.* Chaos 2007 (in press)

## 2. Quantification of Complexity

生物系統都是非常複雜的  
All biological systems are extremely complex.

什麼是複雜性?

### What is Complexity?

The complexity of a biological system should be a measure of the system's *capacity* to adapt and function in an ever changing environment.

The system that can adapt to the most external challenges (stresses) will have the best advantage for survival.

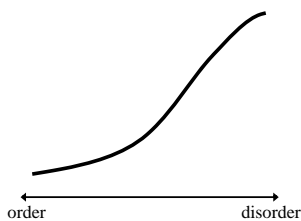
- ✦ 複雜性是生物系統對無時不變環境適應的結果
- ✦ 有適應性才能生存

### 熵能給複雜性定量嗎?

#### Can entropy be used as a complexity measure?

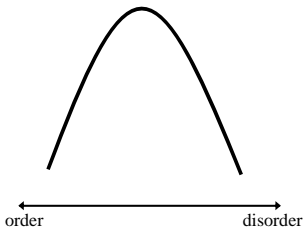
傳統熵的定量法

Conventional entropy measure



理想的複雜性定量

Expected complexity measure



## 3. Time-Frequency Analysis: Adaptive Basis

Spectral analysis for Nonlinear and nonstationary data

### Comparison between FFT and HHT

#### 1. FFT :

$$x(t) = \Re \sum_j a_j e^{i\omega_j t} .$$

#### 2. HHT :

$$x(t) = \Re \sum_j a_j(t) e^{i \int \omega_j(\tau) d\tau} .$$

### What This Means

- ✦ Instantaneous Frequency offers a total different view for nonlinear data: instantaneous frequency with no need for harmonics and unlimited by uncertainty.
- ✦ Adaptive basis is indispensable for nonstationary and nonlinear data analysis
- ✦ HHT establishes a new paradigm of data analysis

## Comparisons

	<b>Fourier</b>	<b>Wavelet</b>	<b>Hilbert</b>
<b>Basis</b>	a priori	a priori	Adaptive
<b>Frequency</b>	Integral Transform: Global	Integral Transform: Regional	Differentiation: Local
<b>Presentation</b>	Energy-frequency	Energy-time-frequency	Energy-time-frequency
<b>Nonlinear</b>	no	no	yes
<b>Non-stationary</b>	no	yes	yes
<b>Uncertainty</b>	yes	yes	no
<b>Harmonics</b>	yes	yes	no

## Conclusion

Complicated data need new tools.

Adaptive method is the only scientifically meaningful way to analyze data.

It is the only way to find out the underlying physical processes; therefore, it is indispensable in scientific research.

It is physical, direct, and simple.

But, we have only started and what we have done is only a scratch of the surface.

***Many of the most significant and interesting challenges of the modern world require boundary-crossing collaborations among scientists and scholars with widely different fields of expertise.***

Allison Richard  
Vice Chancellor, Cambridge University

## Thank You

We have a lot of hard work ahead of us.