Time Series

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Outline I

1. Introduction
   - Definition
   - Examples

- Informal
  - Data varying over time
- Formal
  - Stochastic process indexed on time

$$\{X_t\}$$

Time Series I

- Finance Sector
  - Quarterly earnings per share for the U.S. company Johnson & Johnson
  - Figure 1.01
  - 84 quarters: first quarter of 1960 - last quarter of 1980

Time Series II

- Note:
  - gradually increasing underlying trend
  - regular variation superimposed on the trend that seems to repeat over quarters.

Time Series III

- Finance Sector (contd.)
  - Daily returns (or percent change) of the New York Stock Exchange (NYSE) from 2nd Feb, 1984 to 31st Dec, 1991.
  - Figure 1.04

Time Series IV

- Note:
  - mean of the series appears to be stable with an average return of approximately zero
  - the volatility (or variability) of data changes over time

Time Series V

- Environmental Science
  - The global mean land-ocean temperature index from 1880 to 2009, with the base period 1951-1980
  - Figure 1.02
  - Plot of deviations, measured in degrees centigrade, from the 1951-1980 average

Time Series VI

- Note:
  - apparent upward trend in the series during the latter part of the twentieth century
  - Is it unusual

Time Series VII

- Environmental Science (contd.)
  - Monthly values of an environmental series called the Southern Oscillation Index (SOI) and associated Recruitment (number of new fish)
  - The SOI measures changes in air pressure, related to sea surface temperatures in the central Pacific Ocean
  - Both series are for a period of 453 months ranging over the years 1950-1987.

Time Series VIII

- Note:
  - Both series tend to exhibit repetitive behavior
  - The cycles of the SOI are repeating at a faster rate than those of the Recruitment series.
  - The Recruitment series also shows several kinds of oscillations, a faster frequency that seems to repeat about every 12 months and a slower frequency that seems to repeat about every 50 months.
  - Two series also tend to be somewhat related; it is easy to imagine that somehow the fish population is dependent on the SOI.

Time Series IX

- Physical Science
  - A small .1 second (1000 point) sample of recorded speech for the phrase *aaa* . . . *hhh*,
  - Figure 1.03

Time Series X

- Note:
  - repetitive nature of the signal and the rather regular periodicities.

Time Series XI

- Medical Science
  - Data collected from various locations in the brain via functional magnetic resonance imaging (fMRI).
    - five subjects were given periodic brushing on the hand.
    - stimulus was applied for 32 seconds and then stopped for 32 seconds; thus, the signal period is 64 seconds.
    - sampling rate was one observation every 2 seconds for 256 seconds (n = 128).
    - averaged result over subjects
  - consecutive measures of blood oxygenation-level dependent (bold) signal intensity, which measures areas of activation in the brain
  - Figure 1.06

Time Series XII

- Note:
  - the periodicities appear strongly in the motor cortex series and less strongly in the thalamus and cerebellum.

Time Series XIII

- Earth Science
  - The recording instruments in Scandinavia are observing earthquakes and mining explosions
  - Two phases or arrivals along the surface, denoted by P($t = 1, \ldots, 1024$) and S($t = 1025, \ldots, 2048$), at a seismic recording station
  - Figure 1.07

Time Series XIV

- Note:
  - amplitude ratios of the first phase P to the second phase S, which tend to be smaller for earthquakes than for explosions.
  - a subtle difference exists in the periodic nature of the S phase for the earthquake

Time Series XV

- Two dimensional time-series
  - temperature series x_{s_1,s_2} that represent positions on a 64×36 spatial grid set out on an agricultural field.
  - Figure 1.17

Time Series XVI

- Correlation introduced by sampling of adjacent points in time
  - Break assumption: i.i.d. errors
- Needs special tecniques
- Two approaches of Time Series Analysis
  - Time domain
  - Frequency domain