Lecture 2

Examples of Time Series: Part II

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Areas of application

- Mathematical finance
- Epidemiology
- Climatology
- Biomedical sciences

Johnson & Johnson Quarterly Earnings

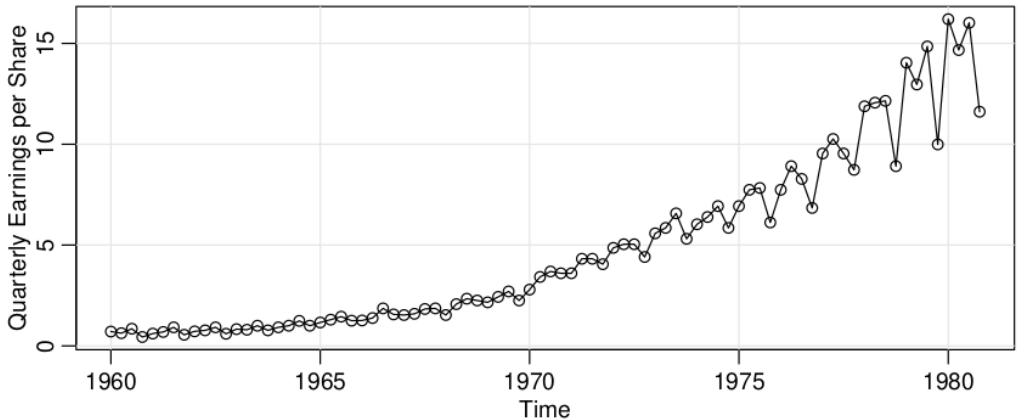

Fig. 1.1. *Johnson & Johnson quarterly earnings per share, 84 quarters, 1960-I to 1980-IV.*

Johnson & Johnson Quarterly Earnings

- There are 84 quarters (21 years) measured from the first quarter of 1960 to the last quarter of 1980.
- Note the gradually increasing underlying trend and the rather regular variation superimposed on the trend that seems to repeat over quarters.
- Methods for analyzing data such as these are: Time series regression and State-space models.

Global Warming

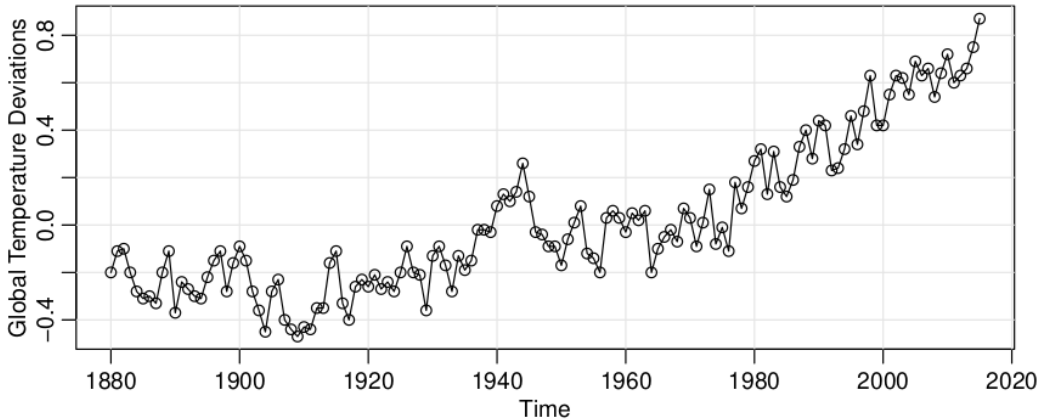

Fig. 1.2. *Yearly average global temperature deviations (1880–2015) in degrees centigrade.*

Global Warming

- The data are the global mean land-ocean temperature index from 1880 to 2015, with the base period 1951–1980.
- We note an apparent upward trend in the series during the latter part of the twentieth century.
- Note also the leveling off at about 1935 and then another rather sharp upward trend at about 1970.
- The question of interest for global warming proponents and opponents is whether the overall trend is natural or human-induced interface.
- The question of trend is of more interest than particular periodicities.

Speech Data

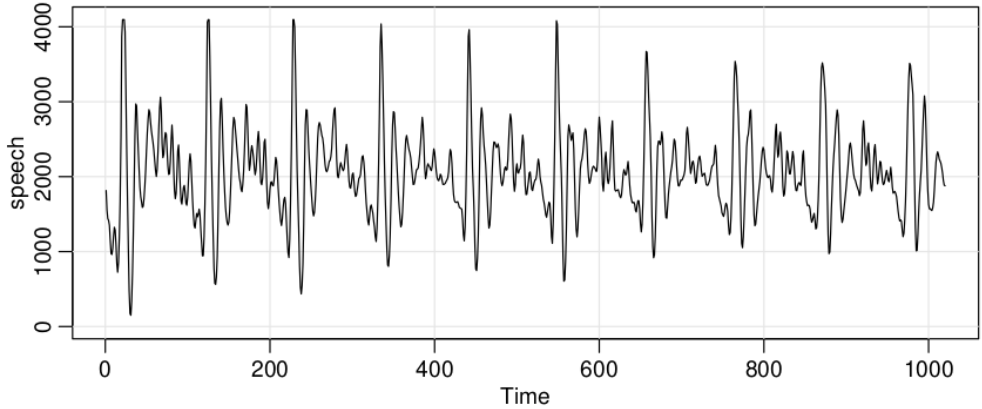

Fig. 1.3. *Speech recording of the syllable aaa $\cdots$ hhh sampled at 10,000 points per second with* $n = 1020$ *points.*

Speech Data

- We note the repetitive nature of the signal and the rather regular periodicities.
- Computer recognition of speech require converting this particular signal into the recorded phrase aaa ... hhh.
- Spectral analysis can be used to produce a signature of this phrase that can be compared with signatures of various library syllables to look for a match.
- One can immediately notice the rather regular repetition of small wavelets. The separation between the packets is known as the pitch period.
- Pitch period represents the response of the vocal tract filter to a periodic sequence of pulses stimulated by the opening and closing of the glottis.

Dow Jones Industrial Average

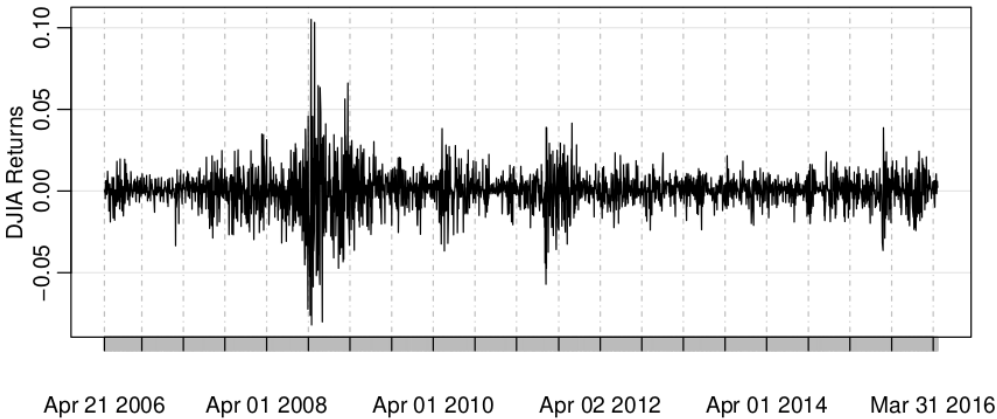

Fig. 1.4. *The daily returns of the Dow Jones Industrial Average (DJIA) from April 20, 2006 to April 20, 2016.*

Dow Jones Industrial Average

- It is easy to spot the financial crisis of 2008 in the figure.
- The data shown here are typical of return data ($R_t = \frac{X_t - X_{t-1}}{X_{t-1}}$).
- The mean of the series appears to be stable with an average return of nearly zero, however, highly volatile periods tend to be clustered together.
- A problem in the analysis of these type of financial data is to forecast the volatility of future returns.
- Models such as ARCH and GARCH models and stochastic volatility models have been developed to handle these problems.

SOI and Fish Population

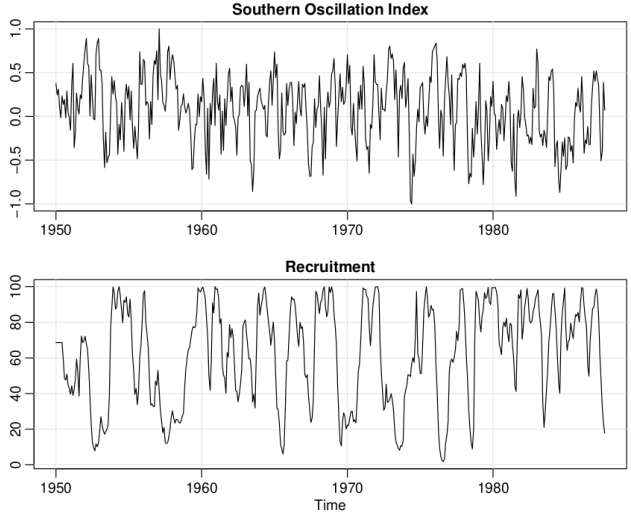

Fig. 1.5. *Monthly SOI and Recruitment (estimated new fish), 1950-1987.*

SOI and Fish Population

- Both series are for a period of 453 months ranging over the years 1950–1987.
- The SOI measures El Nino, i.e., changes in air pressure, related to sea surface temperatures in the central Pacific Ocean.
- Both series exhibit repetitive behavior, with regularly repeating cycles that are easily visible.
- This periodic behavior is of interest because underlying processes of interest may be regular and the rate or frequency of oscillation characterizing the behavior of the underlying series would help to identify them.
- The series show two basic oscillations types, an obvious annual cycle, and a slower frequency that seems to repeat about every 4 years.
- Studying cycles and their strengths is the subject of spectral analysis.
- The two series are also related.

fMRI Imaging

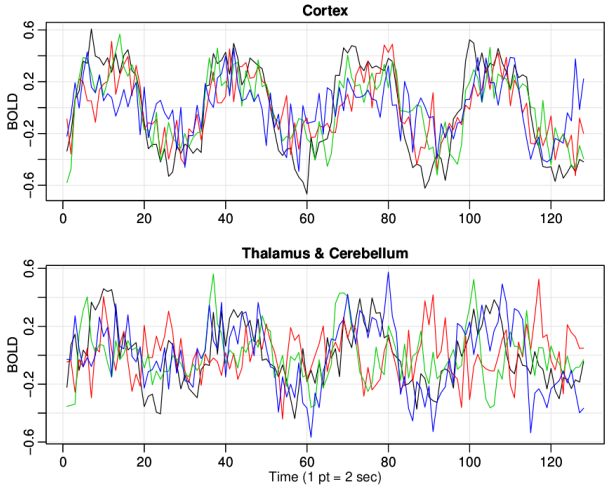

Fig. 1.6. *fMRI data from various locations in the cortex, thalamus, and cerebellum; $n = 128$ points, one observation taken every 2 seconds.*

fMRI Imaging

- Five subjects were given periodic brushing on the hand. The stimulus was applied for 32 seconds and then stopped for 32 seconds; thus, the signal period is 64 seconds.
- The sampling rate was one observation every 2 seconds for 256 seconds (n = 128). For this example, results are averaged over subjects.
- The series are consecutive measures of blood oxygenation-level dependent (bold) signal intensity, which measures areas of activation in the brain.
- Notice that the periodicities appear strongly in the motor cortex series and less strongly in the thalamus and cerebellum.
- The fact that one has series from different areas of the brain suggests testing whether the areas are responding differently to the brush stimulus.
- Analysis of variance techniques accomplish this in classical statistics, and we show in frequency domain.

Earthquakes and Explosions

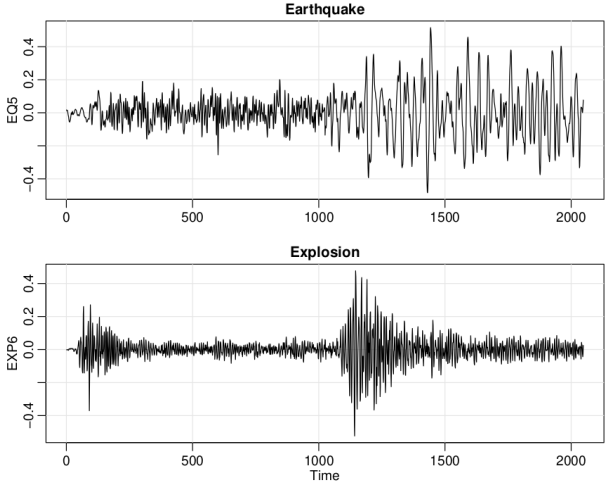

Fig. 1.7. *Arrival phases from an earthquake (top) and explosion (bottom) at 40 points per second.*

Earthquakes and Explosions

- The series represent two phases along the surface, denoted by P $(t = 1, \ldots, 1024)$ and S $(t = 1025, \ldots, 2048)$, at a seismic recorder.
- The general problem of interest is in distinguishing or discriminating between waveforms generated by earthquakes and those generated by explosions.
- Features that may be important are the rough amplitude ratios of the first phase P to the second phase S.
- The ratio of maximum amplitudes appears to be somewhat less than 0.5 for the earthquake and about 1 for the explosion.
- A subtle difference exists in the periodic nature of the S phase for the earthquake.
- We can again think about spectral analysis of variance for testing the equality of the periodic components of earthquakes and explosions.
- We would also like to be able to classify future P and S components from events of unknown origin, leading to the time series discriminant analysis.

Thank you!