Signal Analysis
Biology 5xx
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(1) Temporal and spatial data sets
(2) Auto and Cross-covariance schemes
(3) Fourier and spectral methods
(4) Binary (event counter) type transforms
(5) Non-linear transforms: Norbert Weiner and his kernels
(6) System level performance. ODEs and feedback analysis
(7) Transfer functions. The organism/cell/ecosystem as a transfer function
The b1 shortens during flight
Phase shifts regulate basalare deflections
What Patterns of Activation Control Flight?

The phase varies ever so slightly

M. Frye
Sinwave captures *in vivo* wing hinge deformation

\[ a = 0.6 \text{ mm} \]
\[ \omega = 19 \text{ Hz} \]
Mechanical model predicts tension, but not SR firing dynamics.
SR

Stress

Tension

20 msec

100 msec

20 msec
45 degrees
90 degrees

Frames

X position

Y position

Z position
Simple metrics of a time or space series:

- Means and variances and higher moments of the data.

- Stationarity and ergodicity .... sometimes you need to worry about them

  - If ensemble averages vary with choice of averaging time (or space), the signal is non-stationary.
  - If they do not depend on time (or space), the data is at least weakly stationary.
  - If the means and autocorrelations and all higher moments are time (or space) invariant, the data are strongly stationary.
mean(y) = μ(t_o) = \sum_{i=1}^{N} \frac{y_i}{N} = \frac{1}{t_o} \int_{t}^{t+t_o} y(t) \, dt

\text{var}(y) = \sigma^2(t_o) = \frac{N}{\sum_{i=1}^{N} (y_i - \mu)^2/N} = \frac{1}{t_o} \int_{t}^{t+t_o} (y(t) - \mu)^2 \, dt
The graph illustrates the correlation between $y(t)$ and $y(t + \Delta t)$ over time. The correlation coefficient is shown to be 1, indicating a perfect linear relationship.
The diagram illustrates the concept of correlation between two datasets, $y(t)$ and $y(t + \Delta t)$, over time. The upper graph shows the variation of $y$ with time from $t$ to $t_o$. The lower left graph indicates a trend in the correlation of the datasets $y(t)$ and $y(t + \Delta t)$, with the correlation value $1$ highlighted. The lower right graph depicts the relationship between correlation and the time interval $\Delta t$. This visual representation helps in understanding how data sets are related over time.
Correlation

$y(t)$

$y(t + \Delta t)$

Correlation

$1$

$\Delta t$
Autocorrelation

\[ \phi_{xx} = \frac{\sum y(i)y(i-j)}{N_j} \]

\[ N_j = \begin{cases} N_{\text{total}} - j & \text{if not wrapped} \\ N_{\text{total}} & \text{otherwise} \end{cases} \]
Autocorrelation
\[ \phi_{xx} = \left\{ \frac{\sum y(i) y(i-j)}{N_j} \right\} \]
(N_{total} - j ) if not wrapped
N_{total} otherwise

Autocovariance
\[ C_{xx} = \left\{ \frac{\sum (y(i) - \mu) (y(i-j) - \mu)}{N_j} \right\} \]

Cross correlation
\[ \phi_{xy} = \left\{ \frac{\sum x(i) y(i-j)}{N_j} \right\} \]

Cross covariance
\[ C_{xy} = \left\{ \frac{\sum (x(i) - \mu_x) (y(i-j) - \mu_y)}{N_j} \right\} \]