CHAPTER 1

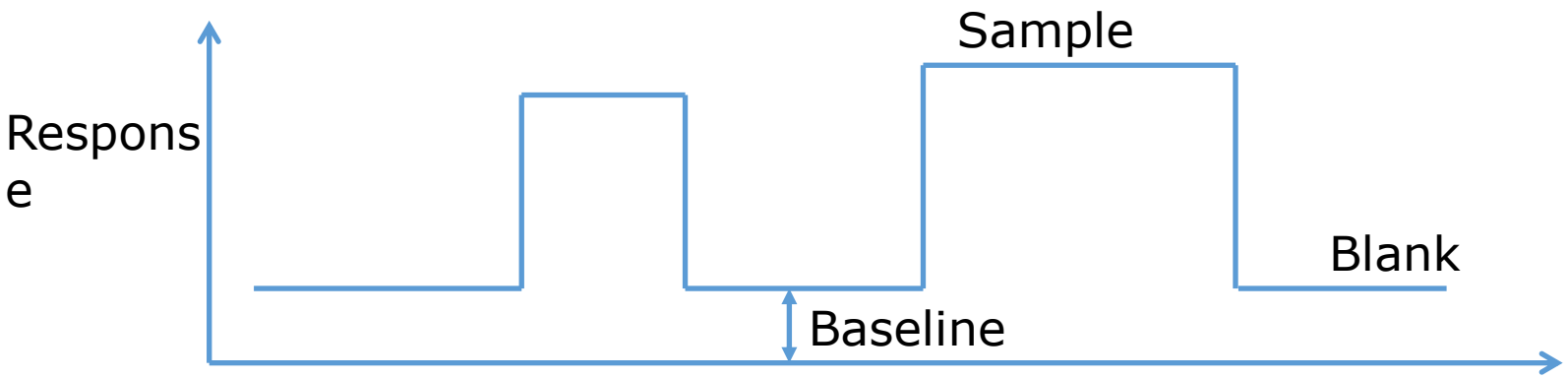
SIGNAL & NOISE

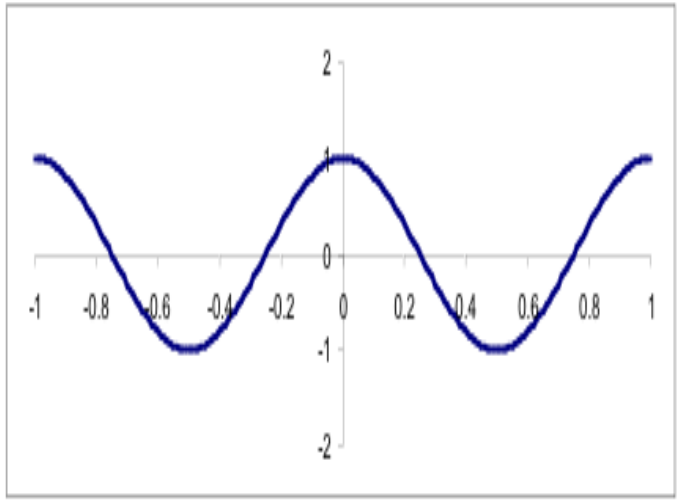
Expected Outcomes

Able to differentiate between signal and noise
Describe the source of noise
Explain the way to minimize the noise and enhance the signal

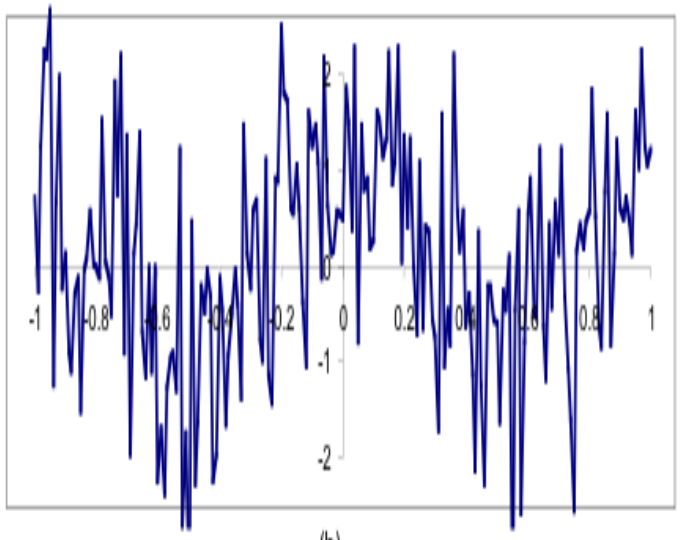
1.1 Signal & Noise

- Sample response : the instrument's response when the analyte is present
- Blank response : the instrument's response when the analyte is absent
- Signal = Sample response – Blank response
- Ideally, blank = 0 ; but never!
- Ideally, baseline is constant in time
- Drift = baseline changes slowly with time





(a)



(b)

Noise

- Random time-dependent change in the instrument's output signal that is unrelated to the analyte response
- These variations make the accuracy lower
- Difference sources of noise
- Important to measure for the detection limit

Signal to Noise ratio (S/N)

- Comparison between desired signal level and noise level
- Noise is independent of signal intensity
- Indicator for noise level
- S/N = (mean)/(std deviation) = x/s = 1/RSD
- S/N = 1 ; means signal = noise (useless info)
- S/N minimum at 3

1.2 Sources of Noise

- Chemical Noise
  - Uncontrollable variables that affect the chemistry of the system under investigation
  - Variations in temperature, pressure, humidity, vibrations

- Instrumental Noise (associated with components of instruments)
  - Thermal or Johnson noise
  - Shot noise
  - Flicker noise
  - Environmental noise

Thermal Noise

- Caused by the thermal agitation of electrons or charge carriers in resistor, capacitor or resistive elements in instrument
- Charge inhomogeneities creates voltage fluctuation
- Present even at zero current
- RMS of noise voltage :

$$v_n = \sqrt{4k_B T R \Delta f}$$

- Bandwidth lower ; thermal noise lower
- BUT bandwidth lower ; instrument slower in responding to signal ; more time for measurement
- Lower R ; lower thermal noise
- Lower T ; lower thermal noise

Shot Noise

- Electrons or charge particles cross pn junction

$$\sigma_i = \sqrt{2\,q\,I\,\Delta f}$$

- Can be minimized by lowering bandwidth

Flicker Noise

- Inversely proportional to the frequency signal (1/f)
- Frequency dependence; significant at lower frequency

Environmental Noise

- Noise from surroundings
- Caused by the conductors in instruments; they act as antenna for picking up electromagnetic radiation and convert to electrical signal

1.3 Signal to Noise Enhancement

- Hardware
  - Grounding/Shielding
  - Filter
  - Chopping
  - Lock-in amplifier
  - Modulation

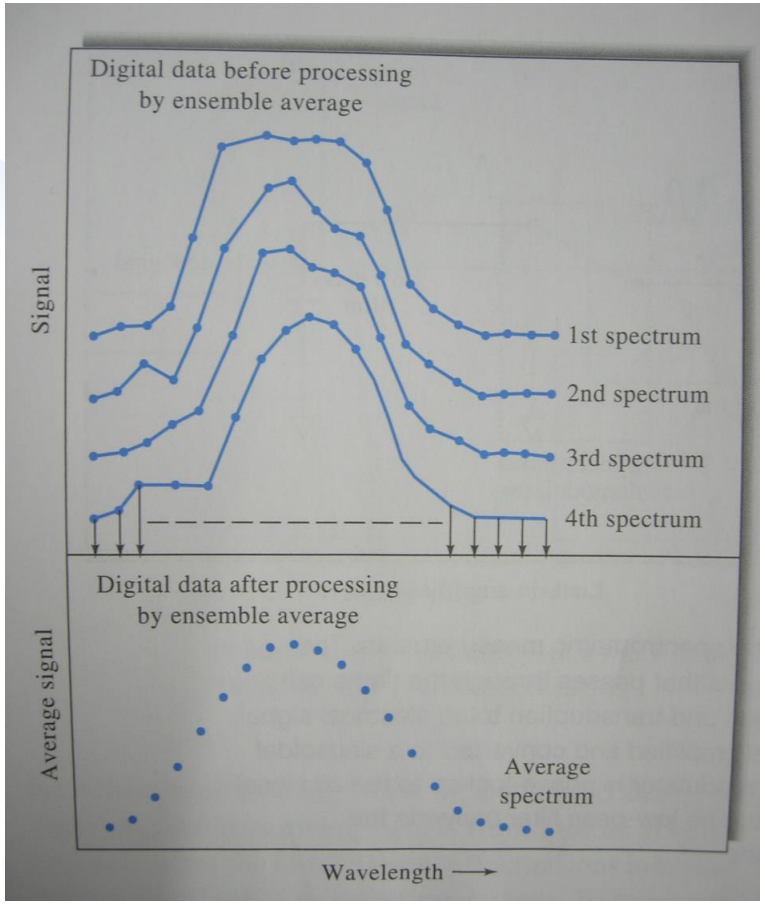
- Software
  - Ensemble averaging
  - Boxcar averaging
  - Digital filtering
  - Correlation methods

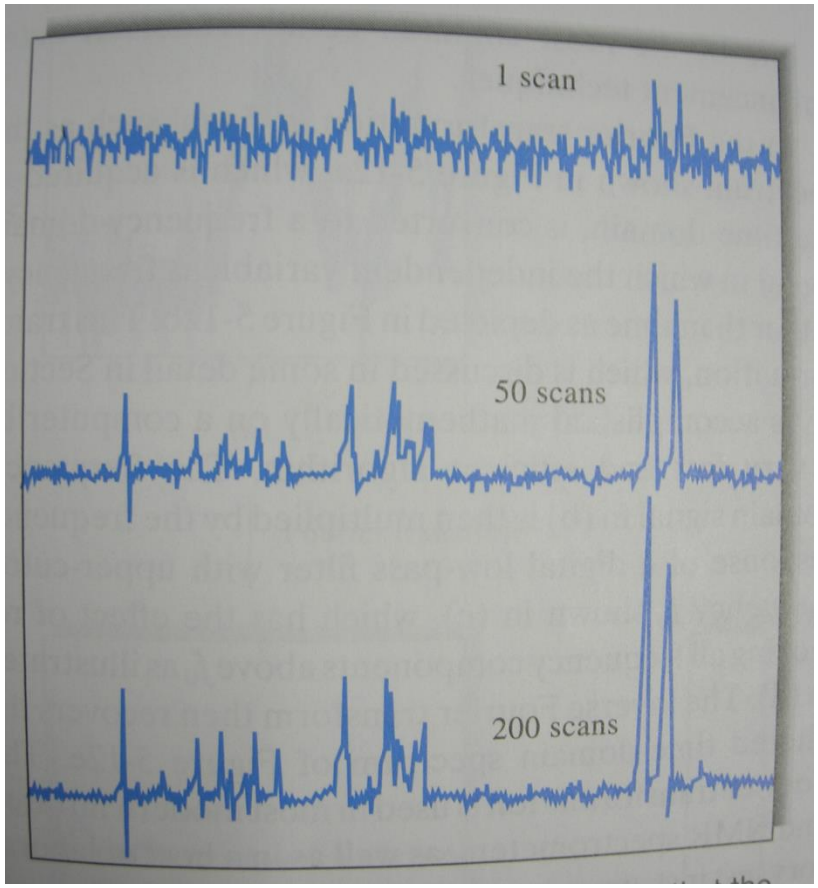
Ensemble Averaging

- Successive sets of data stored in memory as array
- Summed up point by point (co-addition)
- Data are averaged

- WHY ensemble averaging can increase the S/N ratio? Explain from mathematical formulas.

Ensemble Averaging





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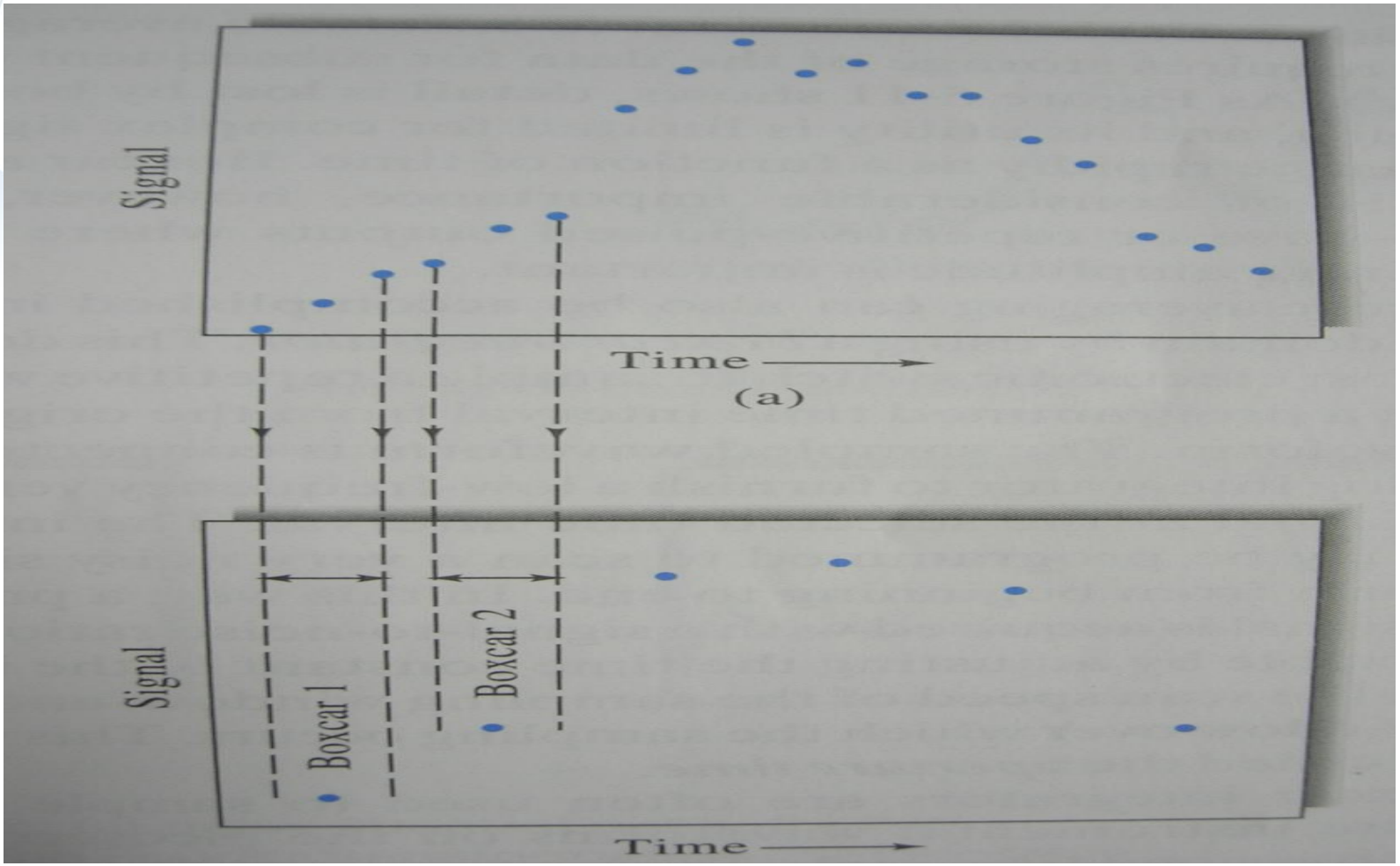
Boxcar Averaging

- Smoothing irregularities
- Assume that irregularities are the result of noise
- Assume that the analog analytical signal varies only slowly with time and the average small number of adjacent points is better measure of the signal than individual points
- Drawbacks: detail is lost ; cannot be used for signal changes rapidly with time

Boxcar Averaging



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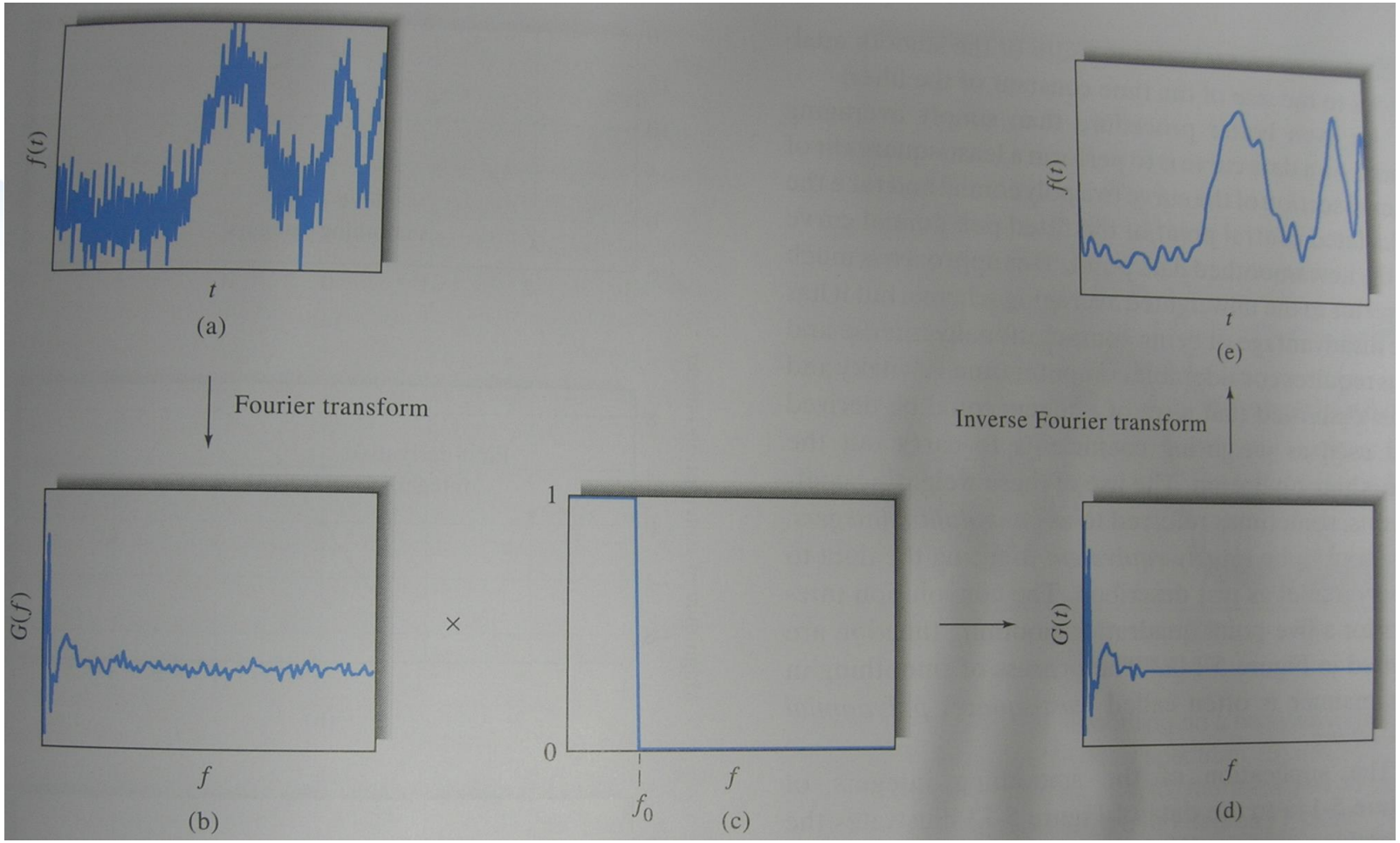
Digital Filtering

- Ensemble averaging
- Fourier transformation
- Least-squares polynomial smoothing
- Correlation

Fourier Transformation



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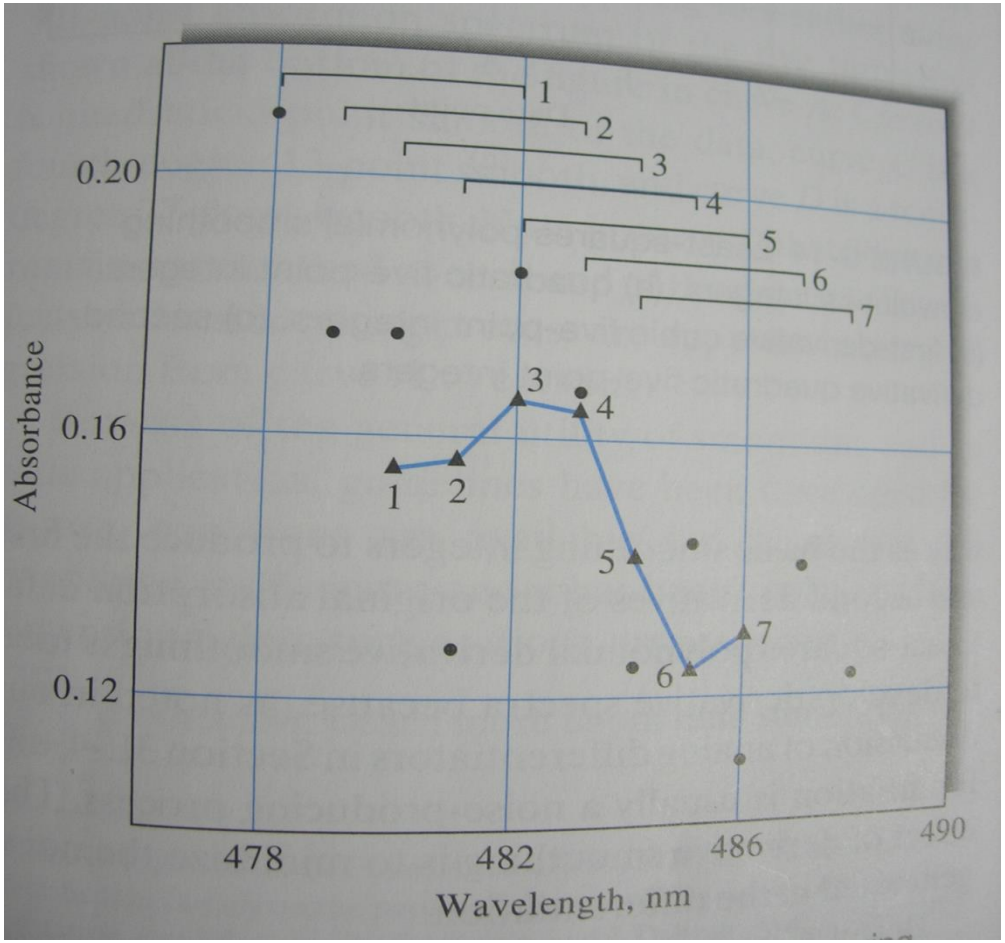
Least-squares Polynomial Smoothing



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