# Chapter 4
# Event Detection-1

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# Introduction

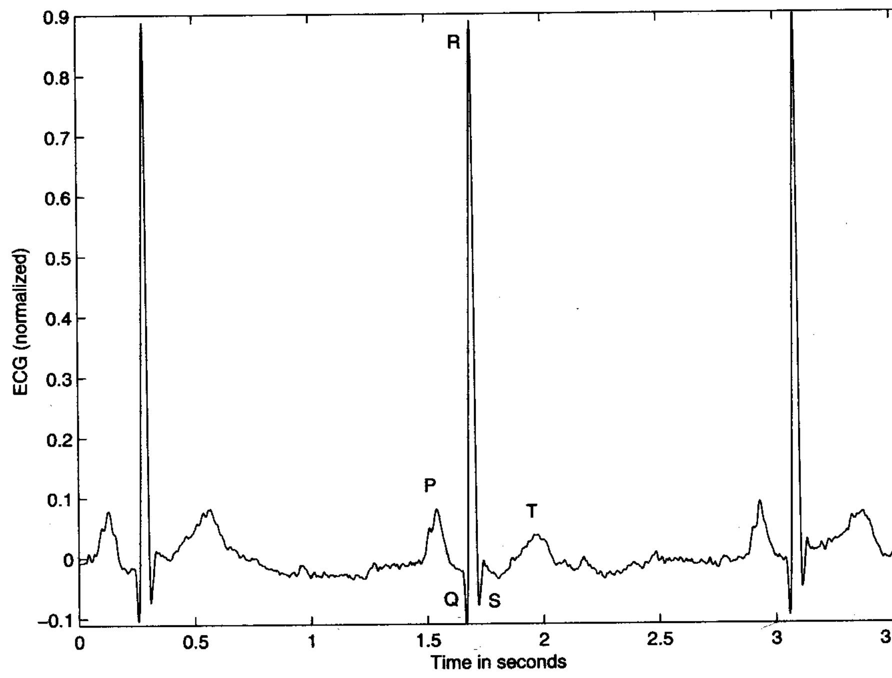
- Biomedical signals carry signatures of physiological events
- Part of a signal related to a specific event of interest is referred to as an *"epoch"*
- Analysis requires identification of epochs
  - For monitoring and diagnosis
- The corresponding waveform may be segmented and analyzed in terms of its
  - Amplitude, waveform, time-duration, intervals between events, energy distribution, frequency content

# Problem statement

- Given a biomedical signal, identify discrete signal epochs and correlate them with events in the related physiological process

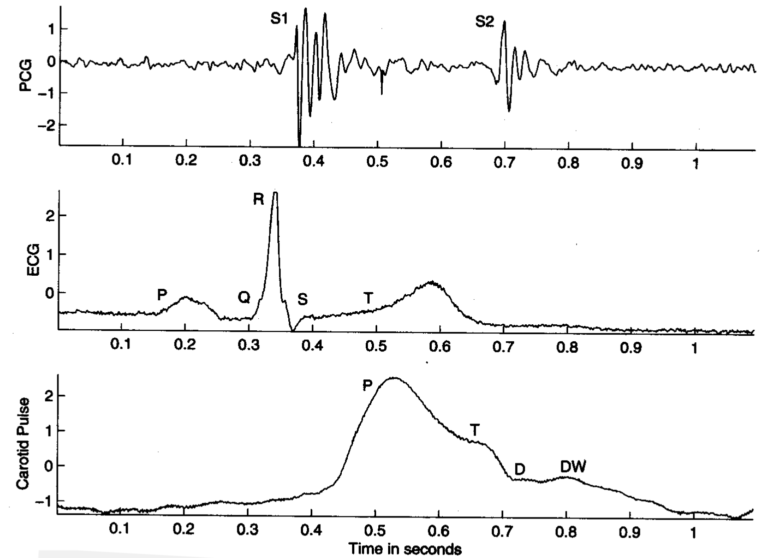
# Normal ECG

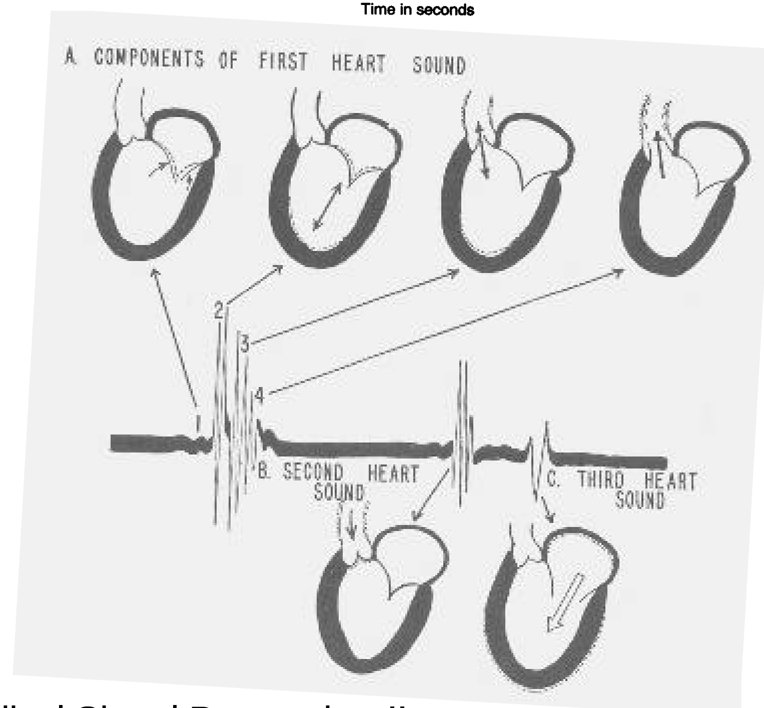
- Slow P wave: 0.1-0.2 mV 60-80 ms
- PQ segment: AV delay 60-80 ms
  - isoelectric
- QRS complex: sharp biphasic or triphasic wave of about 1 mV amplitude and 80 ms duration
- ST segment: 100-120 ms
  - Isoelectric
- Slow T wave: 0.1-0.3 mV and duration 120-160 ms



# PCG signal

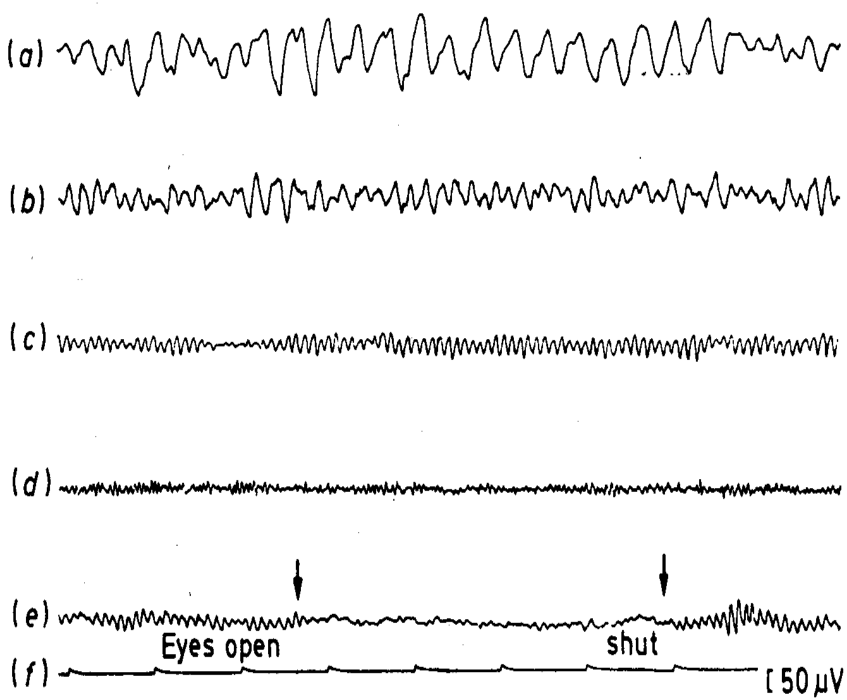
- S1 occurs at the onset of ventricular contraction
  – Corresponds in timing to the QRS complex in the ECG signal
- S2 is caused by the closure of the semilunar valves (aortic and pulmonary valves)



# EEG signals

- Delta waves
  - 0.5<= f < 4 Hz, appear at deep-sleep stages
- Theta waves
  - 4 <= f < 8 Hz, appear at the beginning stages of sleep
- Alpha waves
  - 8 <= f < 13 Hz, principal resting rhythm
  - Auditory and mental arithmetic tasks with eyes closed
- Beta waves
  - f > 13 Hz, background activity in tense and anxious subjects



# Detection of Events and Waves-1

- QRS detection
  - – Derivative-based methods
  - – Pan-Tompkins algorithm
- Correlation analysis of EEG channels
  - – Detection of EEG rhythms
  - – Template matching for EEG spike-and-wave detection

# Detection of Events and Waves-2

- Matched filter
- P-wave detection

# Applications

- ECG rhythm analysis

# QRS Detection

- Derivative-based methods
- Pan-Tompkins algorithm

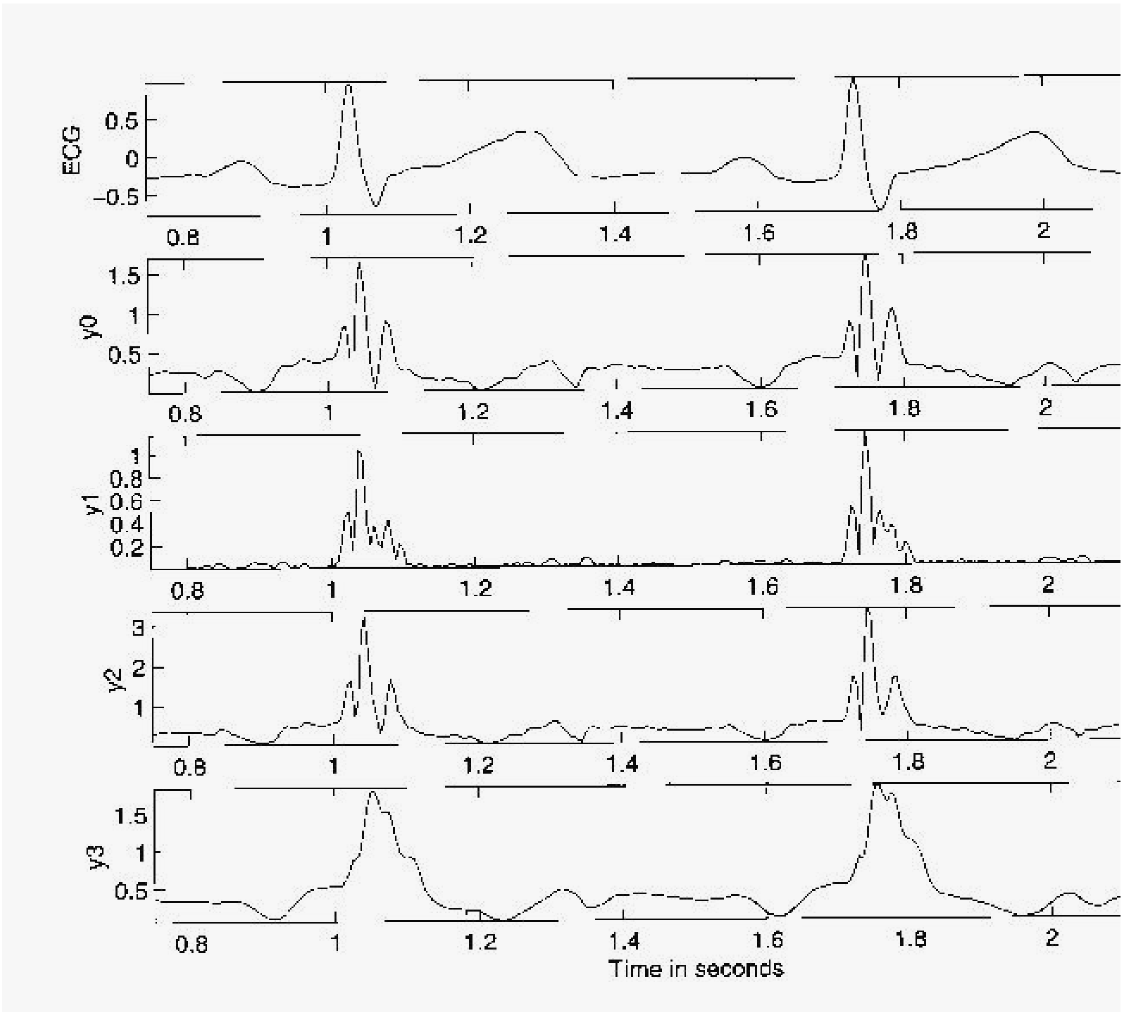
# Derivative-based methods

- QRS might not always be the highest wave in a cardiac cycle
  - artifacts may upset the peak search algorithm
- QRS complex has the largest slope (rate of change of voltage)
- Rate of change = derivative operator (d/dt)
- Derivative operator:
  - P and T waves will be suppressed
  - Output is the highest at the QRS

# Derivative-based algorithm

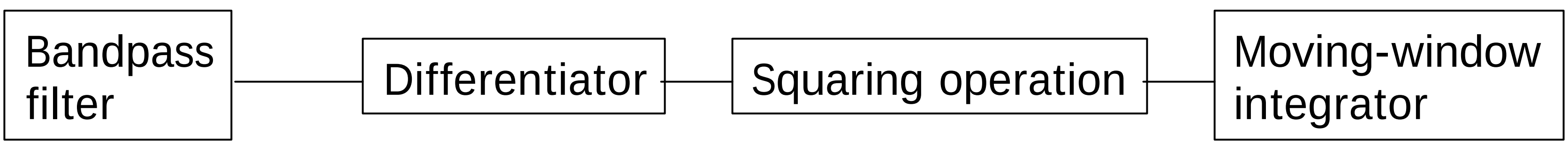
- Balda et al proposed an algorithm
  - Three-point first derivative
    - $y0[n] = | x[n] - x[n-2] |$
  - Second derivative
    - $y1[n] = | x[n] - 2x[n-2] + x[n-4] |$
  - The two results are weighted and combined
    - $y2[n] = 1.3\ y0[n] - 1.1\ y1[n]$
  - The result y2[n] is scanned with a threshold of 1.0
  - Whenever threshold is crossed
    - Subsequent 8 samples also tested against the same threshold
    - If at east 6 pass the threshold test
  - The segment of eight samples is taken to be a part of a QRS complex

# Figure 4.2


ECG
0.5
0
−0.5
0.8
1
1.2
1.4
1.6
1.8
2
y0
1.5
1
0.5
y1
1
0.8
0.6
0.4
0.2
y2
3
2
1
y3
1.5
1
0.5
Time in seconds

# The Pan-Tompkins algorithm

- Pan and Tompkins proposed a real-time QRS detection algorithm based on
  - Slope, amplitude, and width of QRS complexes



# Algorithm details

- Recursive LPF
  - $H(z) = (1/32)( (1\text{-}z^{-6})^2 )/( (1\text{-}z^{-1})^2 )$
  - $y[n] = 2\ y[n-1] - y[n-2] + (1/32)[\ x[n]- 2x[n-6]+x[n-12]\ ]$
- Sampling rate = 200 Hz, fc = 11 Hz
- Filter introduces 5 samples of delay (25 ms)

# Algorithm details

- HPF
- Allpass filter minus a LPF
  - $H\_lp(z) = (1-z^{-32})/(1-z^{-1})$
  - $y[n] = y[n-1] + x[n] - x[n-32]$
- $H\_hp(z) = z^{-16} – (1/32)H\_lp(z)$
  - $p[n] = x[n-16] – (1/32)[y[n-1] + x[n] - x[n-32]]$
- fc = 5 Hz
- Filter introduces 80 ms of delay

# Derivative operator

- $y[n] = (1/8) [ 2x[n] + x[n-1] – x[n-3] – 2x[n-4] ]$
  - Approximates the ideal d/dt operator up to 30 Hz
- Suppresses P and T waves

# Squaring

- Makes the results positive and emphasizes large differences arising from QRS complexes
- Small differences arising from P and T waves are suppressed

# Integration

- Multiple peaks within the duration of a single QRS complex
- Smoothing of the output of the preceding operations through a moving window integration filter
  - $y[n] = (1/N) [ x[n – (N-1)] + x[n – (N-2) + … + x[n] ]$
  - N: window width (N=30 found to be suitable for fs=200 Hz)

# Adaptive thresholding

- A peak is said to be detected whenever the final output changes direction within a specified interval

# Figure 4.6

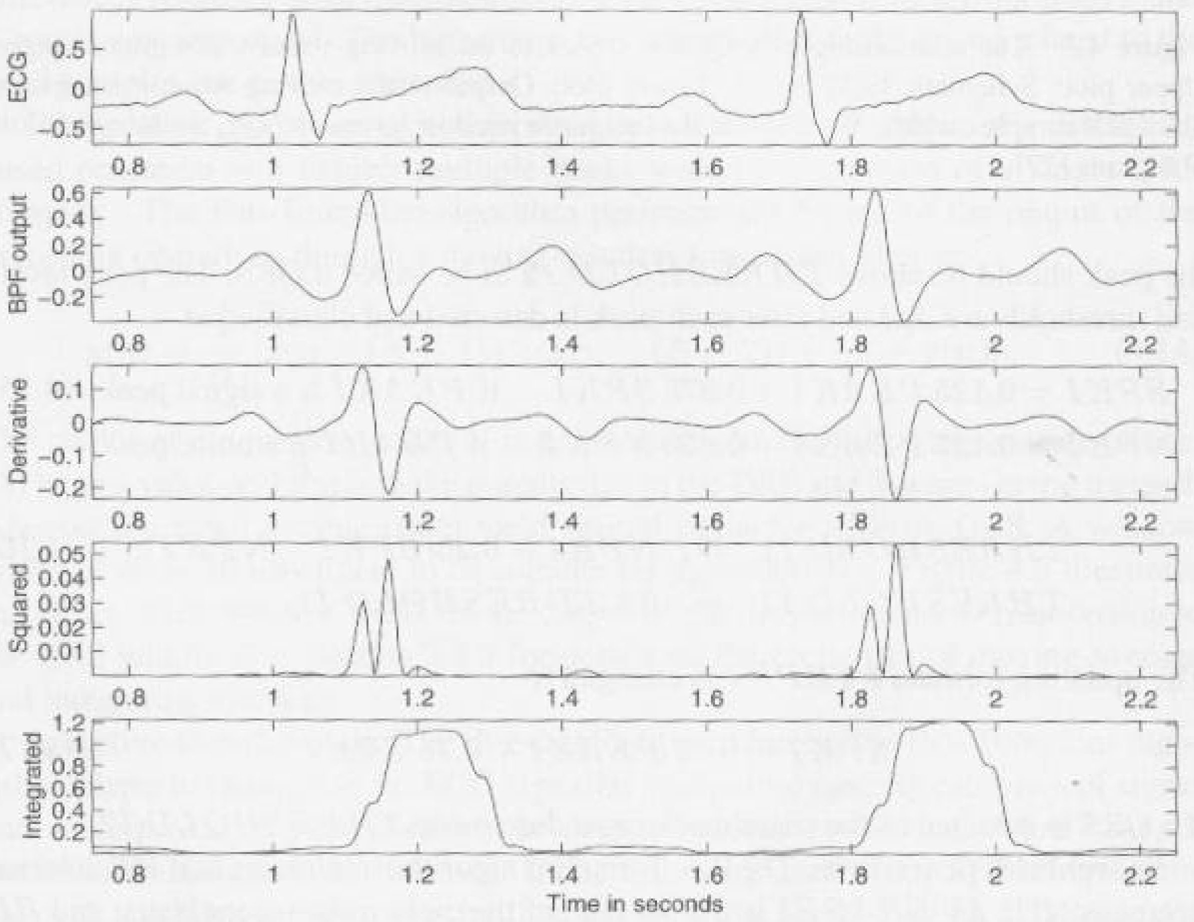



**Figure 4.6** Results of the