Chapter 2:
Concurrent, Coupled and Correlated Processes

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Introduction

- Most biological processes within a body are not independent of one another;
- Rather, they are mutually correlated and bound together by physical or physiological control and communication phenomena
- Questions:
  - How do we recognize the existence of concurrent, coupled, and correlated phenomena?
  - How do we obtain the corresponding signals and identify the correlated features?

Problem statement

- Determine the correspondences, correlation, and inter-relationships present between concurrent signals related to a common underlying physiological system or process, and identify their potential applications.

ECG and PCG

- ECG
  - 12 channels simultaneously recorded signals
  - Easy to read and interpret for clinicians
- PCG
  - More complex signal
  - Cannot be visually analyzed
  - Gross features such as
    - Murmurs, time delays

Problem

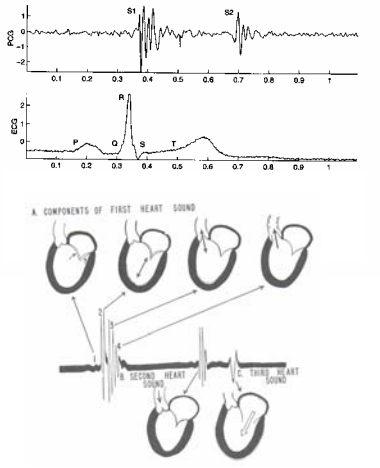
- Identify the beginning of S1 in a PCG and extract the heart sound signal over one cardiac cycle

Solution

- Record ECG and PCG together

Solution:
ECG and PCG recorded together

- QRS -> ventricular contraction
- AV valves shut -> initial vibrations of S1
- S1 begins immediately after QRS complex
- QRS detection is easy
- QRS complex can be used to segment PCG record into cardiac cycles



PCG and Carotid Pulse

- Identification of the diastolic segment of the PCG may be required in some applications.
- Ventricular systole ends with the closure of aortic and pulmonary valves
- The end of contraction is also indicated by T wave in ECG
- S2 appears slightly after the end of T wave
- T wave is not a reliable indicator
  - Smooth and low-amplitude wave
  - Sometimes not recorded at all
  - ST elevation or depression may occur

Problem

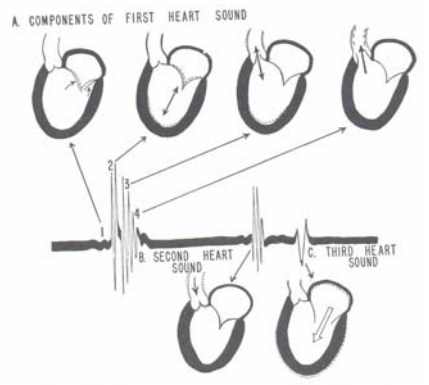
- Identify the beginning of S2 in a PCG signal

Solution

- Record PCG and Carotid Pulse together

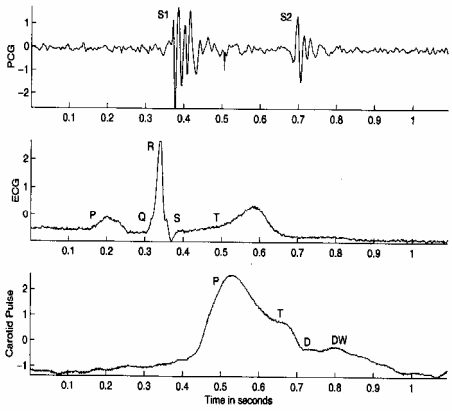
Solution: CP signal with PCG

- Aortic valve closes -> Deceleration and reversal of blood flow in the aorta -> Sudden drop in the BP within the aorta ->
- Downward slope due to the end of systolic activity -> Notch in aortic pressure wave (D)



CP signal with PCG signal

- Notch in aortic pressure wave (D)
- Aortic pressure measurement is invasive
- Carotid Pulse can be used instead of aortic pressure
  - Problem is the delay
  - Noninvasive
  - Average S2-D delay = 42.6 ms std = 5 ms
  - This delay should be subtracted from D to obtain the beginning of S2



ECG and Atrial Electrogram (EG)

- RR interval analysis neglects atrial activity
- AV delay plays an important role in coordinated contraction of atria and ventricles
- PR interval is also important
- P wave may not be measured by external ECG

Problem

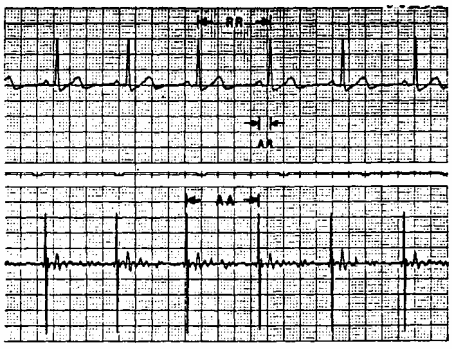
- Obtain an indicator of atrial contraction to measure the PR interval

Solution

- Record external ECG and atrial EG using a pill-electrode together

Solution: Pill-electrode

- Pill-electrode
  - Swallowed and lowered through the esophagus to a position close to the left atrium (bipolar electrode)
  - Suspended at that position
- 2-5 times higher gain than external ECG
  - 5-100 Hz bandpass filter
  - SNR is 10



Application:
Segmentation of the PCG into systolic and diastolic parts