Project 1: Patient Monitoring

Multi-parameter Signal Analysis for Patient Monitoring

ECE 313 – Section G

Spring 2025

Multi-parameter Signal Analysis for Patient Monitoring

In this Project, you will do:

- Analyze data by calculating/plotting the empirical distributions using physiological monitoring data
- Compare an empirical distribution with an estimated normal distribution from estimated parameters (μ, σ)
- Determine a threshold to find abnormalities of each monitored signal
- Generate alarms for each signals
- Implement a voter that makes the final decision
- Evaluate the performance of your system

and you will learn:

- to calculate the pdf/ pmf and cdf based on empirical data
- the characteristics of pmf and pdf
- the relationship between pmf, pdf and cdf
- properties of the Normal distribution
- how to evaluate the performance of a monitoring system which has false alarms and missed detections

Multi-parameter Signal Analysis for Patient Monitoring

- Assume you are an engineer working at a medical device company ACME
- You are assigned to design a reliable patient monitoring system which analyzes the correlated physiological signals collected from the patient's body, and generates alarms for abnormalities.
- You are given a set of three correlated physiological signals collected from the biomedical sensors attached to the patient's body:
  - S1: Heart Rate (HR)
  - S2: Pulse Rate (PR)
  - S3: Respiration Rate (RESP)

Project 1: Description

You design a multi-parameter and fusion monitoring system where

- The signals are passed through three processing units (P1, P2, and P3, respectively), called threshold functions, to detect patient abnormalities.
- Each threshold function will generate an alarm whenever a data sample of the corresponding signal exceeds a pre-defined threshold. A “1” on the output of each function indicates an alarm and a “0” corresponds to absence of an alarm.
- A majority voter function then generates the final output, based on the value that the majority of the threshold functions agreed upon.

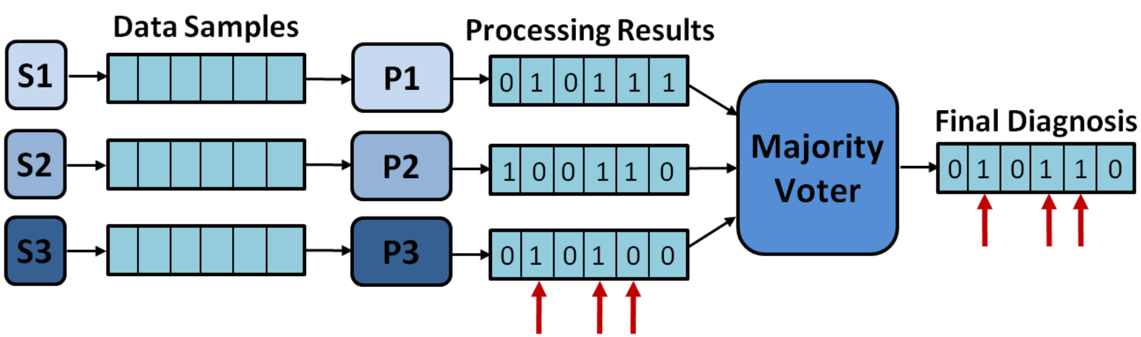

Figure 1.

Majority Voter Example

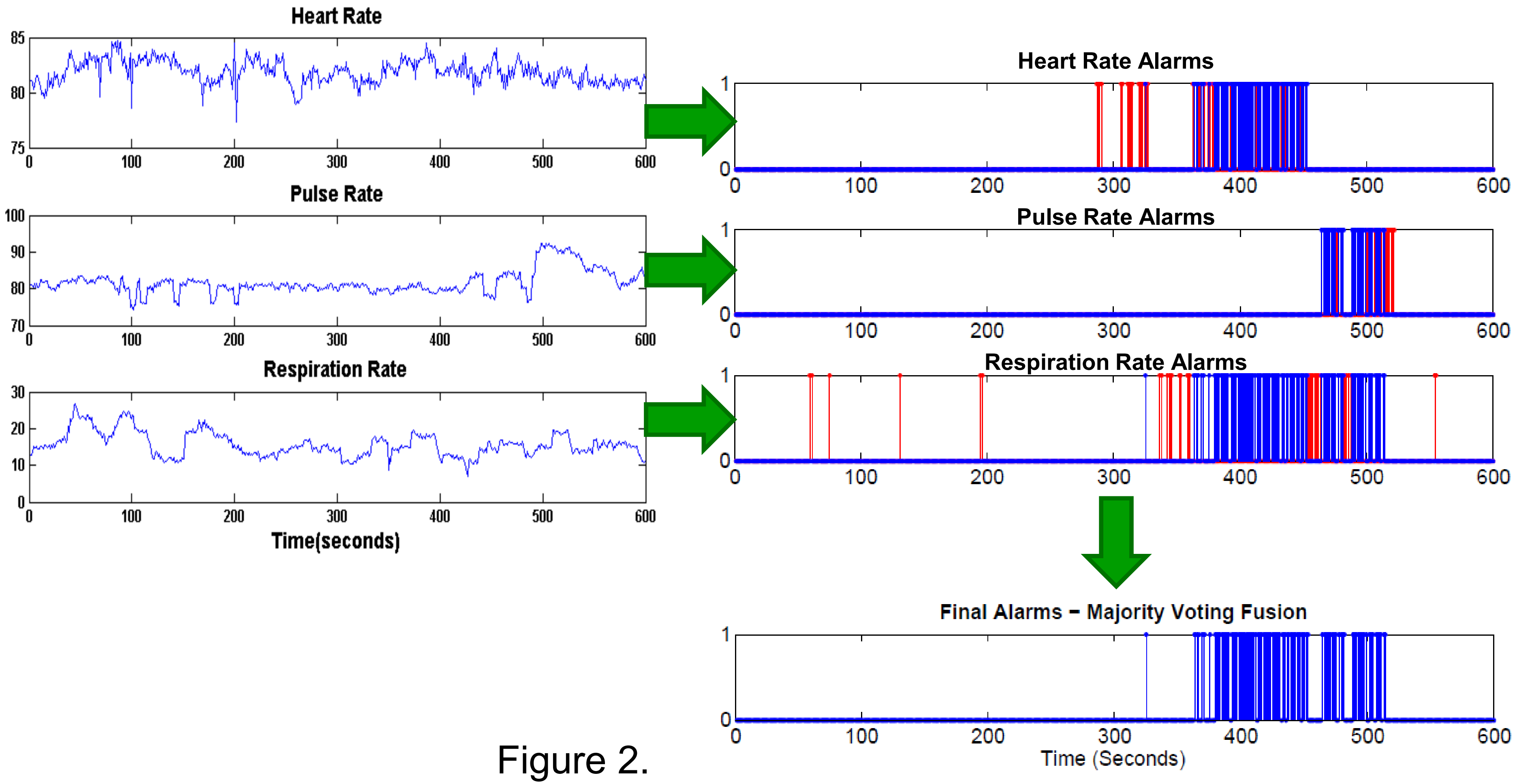

Figure 2.

Project 1: Voter Success Examples

- Assume that by talking to the physician, we know that in the time interval T the patient experiences an abnormality and an alarm should be raised (The output from the monitoring system should be "1").

➢ If P1 and P2 functions generate "1", but P3 generates a "0", then the majority voter will generate a "1" (an alarm) on the final output, indicating a patient abnormality.

  – This means that P3 missed a ***true alarm***, and voter ***fixed a missed detection*** on P3.

- Assume that for another time interval we know the patient experienced no abnormality and no alarms should be raised (The output should be "0").

➢ If P1 generates a "1", P2 and P3 functions generate "0", then the majority voter will generate a "0" (no alarm) on the final output, indicating no patient abnormality.

  – This means that P1 raised a ***false alarm***, and the voter ***masked a false alarm*** on P1.

Project 1: Voter Failure Examples

- Again, assume that by talking to the physician, we know that in the time interval T the patient experienced an abnormality and an alarm should be raised (The output from the monitoring system should be “1”).

➢ But both P1 and P2 functions generate “0”, while P3 generates a “1”, then the majority voter will generate a “0” (no alarm) on the final output, wrongly indicating that there is no patient abnormality.
  – This means that P3 raised a ***true alarm***, but because P1 and P2 had ***missed detection***, the voter output was erroneous. We call this a ***missed detection.***

- Now assume that for another time interval we know the patient experienced no abnormality and no alarms should be raised (The output should be “0”).

➢ If P1 generates a “0”, but P2 and P3 functions generate “1”, then the majority voter will generate a “1” (an alarm) on the final output, indicating a patient abnormality.
  – This means that P1 raise a ***true alarm***, P2 and P3 raised ***false alarms***, and the voter output was erroneous. We call this a ***a false alarm***.

Project 1: Task 0

Task 0:

- You are provided with a dataset *patient_data.mat*.
- *patient_data* consists of 2 variables:
  - *data* (physiological signals) and *golden_alarms* (physician annotations)
- *data* is an array of 3 rows and 30,000 columns
  - The first row corresponds to the Heart Rate (HR), the second row corresponds to the Pulse Rate(PR), and the third row corresponds to the Respiration Rate (RESP)
  - Each column corresponds to a data sample (there are 30,000 data entries for each signal)
  - Sampling rate is 1 sample/second and the whole period is 30,000 seconds.
- *golden_alarms* is a single row of 3,000 columns, each entry is a binary value
  - Each entry corresponds to an interval containing 10 samples.
  - Any of the samples contain an alarm in a given interval, the entry is 1 if it contains alarms, 0 if there are no alarms.

Write a code that does the following in Python:

- Load the provided data set.
- In order to visualize the data, as in Figure 2, plot all three signals over time.
- Useful libraries: scipy, numpy, matplotlib.