

Task_ECG

July 3, 2025

1 Task_ECG

1.1 Task description

Each student is assigned a variant of the same ECG processing task. The goal is to: - Preprocess a simulated or real ECG signal. - Apply bandpass filtering to remove baseline drift and high-frequency noise. - Detect R-peaks in the filtered signal. - Calculate and plot heart rate over time. - Interpret the results based on signal quality and parameter choices.

The general structure of the task: 1. Load or simulate an ECG signal of a given duration and sampling rate. 2. Apply a bandpass filter with given cutoff frequencies. 3. Detect R-peaks using neurokit2 or a custom algorithm. 4. Compute instantaneous heart rate and visualize it. 5. Comment on how filtering affects R-peak detection.

Variant 6: - Duration: 12 s, - Sampling Rate: 500 Hz, - Filter: 1–50 Hz,

1.2 Python code

Installation of the necessary Python libraries

```
[1]: ! pip install wfdb biosppy neurokit2
# ! pip install --upgrade FuzzyTM neurokit2 wfdb biosppy
```

Collecting wfdb

Downloading wfdb-4.3.0-py3-none-any.whl.metadata (3.8 kB)

Collecting biosppy

Downloading biosppy-2.2.3-py2.py3-none-any.whl.metadata (6.0 kB)

Collecting neurokit2

Downloading neurokit2-0.2.11-py2.py3-none-any.whl.metadata (37 kB)

Collecting aiohttp>=3.10.11 (from wfdb)

Downloading aiohttp-3.12.13-cp312-cp312-win_amd64.whl.metadata (7.9 kB)

Requirement already satisfied: fsspec>=2023.10.0 in

e:\users\dawid\anaconda3\lib\site-packages (from wfdb) (2024.6.1)

Requirement already satisfied: matplotlib>=3.2.2 in

e:\users\dawid\anaconda3\lib\site-packages (from wfdb) (3.9.2)

Requirement already satisfied: numpy>=1.26.4 in

e:\users\dawid\anaconda3\lib\site-packages (from wfdb) (1.26.4)

Collecting pandas>=2.2.3 (from wfdb)

Downloading pandas-2.3.0-cp312-cp312-win_amd64.whl.metadata (19 kB)

Requirement already satisfied: requests>=2.8.1 in

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e:\users\dawid\anaconda3\lib\site-packages (from wfdb) (2.32.3)
Requirement already satisfied: scipy>=1.13.0 in
e:\users\dawid\anaconda3\lib\site-packages (from wfdb) (1.13.1)
Requirement already satisfied: soundfile>=0.10.0 in
e:\users\dawid\anaconda3\lib\site-packages (from wfdb) (0.13.1)
Collecting bidict (from biosppy)
  Downloading bidict-0.23.1-py3-none-any.whl.metadata (8.7 kB)
Requirement already satisfied: h5py in e:\users\dawid\anaconda3\lib\site-
packages (from biosppy) (3.11.0)
Requirement already satisfied: scikit-learn in
e:\users\dawid\anaconda3\lib\site-packages (from biosppy) (1.5.1)
Collecting shortuuid (from biosppy)
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Requirement already satisfied: six in e:\users\dawid\anaconda3\lib\site-packages
(from biosppy) (1.16.0)
Requirement already satisfied: joblib in e:\users\dawid\anaconda3\lib\site-
packages (from biosppy) (1.4.2)
Requirement already satisfied: opencv-python in
e:\users\dawid\anaconda3\lib\site-packages (from biosppy) (4.11.0.86)
Requirement already satisfied: pywavelets in e:\users\dawid\anaconda3\lib\site-
packages (from biosppy) (1.7.0)
Collecting mock (from biosppy)
  Downloading mock-5.2.0-py3-none-any.whl.metadata (3.1 kB)
Collecting aiohappyeyeballs>=2.5.0 (from aiohttp>=3.10.11->wfdb)
  Downloading aiohappyeyeballs-2.6.1-py3-none-any.whl.metadata (5.9 kB)
Requirement already satisfied: aiosignal>=1.1.2 in
e:\users\dawid\anaconda3\lib\site-packages (from aiohttp>=3.10.11->wfdb) (1.2.0)
Requirement already satisfied: attrs>=17.3.0 in
e:\users\dawid\anaconda3\lib\site-packages (from aiohttp>=3.10.11->wfdb)
(23.1.0)
Requirement already satisfied: frozenlist>=1.1.1 in
e:\users\dawid\anaconda3\lib\site-packages (from aiohttp>=3.10.11->wfdb) (1.4.0)
Requirement already satisfied: multidict<7.0,>=4.5 in
e:\users\dawid\anaconda3\lib\site-packages (from aiohttp>=3.10.11->wfdb) (6.0.4)
Collecting propcache>=0.2.0 (from aiohttp>=3.10.11->wfdb)
  Downloading propcache-0.3.2-cp312-cp312-win_amd64.whl.metadata (12 kB)
Collecting yarl<2.0,>=1.17.0 (from aiohttp>=3.10.11->wfdb)
  Downloading yarl-1.20.1-cp312-cp312-win_amd64.whl.metadata (76 kB)
Requirement already satisfied: contourpy>=1.0.1 in
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(1.2.0)
Requirement already satisfied: cycler>=0.10 in
e:\users\dawid\anaconda3\lib\site-packages (from matplotlib>=3.2.2->wfdb)
(0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in
e:\users\dawid\anaconda3\lib\site-packages (from matplotlib>=3.2.2->wfdb)
(4.51.0)
Requirement already satisfied: kiwisolver>=1.3.1 in

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e:\users\dawid\anaconda3\lib\site-packages (from matplotlib>=3.2.2->wfdb)
(1.4.4)
Requirement already satisfied: packaging>=20.0 in
e:\users\dawid\anaconda3\lib\site-packages (from matplotlib>=3.2.2->wfdb) (24.1)
Requirement already satisfied: pillow>=8 in e:\users\dawid\anaconda3\lib\site-
packages (from matplotlib>=3.2.2->wfdb) (10.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in
e:\users\dawid\anaconda3\lib\site-packages (from matplotlib>=3.2.2->wfdb)
(3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in
e:\users\dawid\anaconda3\lib\site-packages (from matplotlib>=3.2.2->wfdb)
(2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in
e:\users\dawid\anaconda3\lib\site-packages (from pandas>=2.2.3->wfdb) (2024.1)
Requirement already satisfied: tzdata>=2022.7 in
e:\users\dawid\anaconda3\lib\site-packages (from pandas>=2.2.3->wfdb) (2023.3)
Requirement already satisfied: charset-normalizer<4,>=2 in
e:\users\dawid\anaconda3\lib\site-packages (from requests>=2.8.1->wfdb) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in
e:\users\dawid\anaconda3\lib\site-packages (from requests>=2.8.1->wfdb) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in
e:\users\dawid\anaconda3\lib\site-packages (from requests>=2.8.1->wfdb) (2.2.3)
Requirement already satisfied: certifi>=2017.4.17 in
e:\users\dawid\anaconda3\lib\site-packages (from requests>=2.8.1->wfdb)
(2025.1.31)
Requirement already satisfied: threadpoolctl>=3.1.0 in
e:\users\dawid\anaconda3\lib\site-packages (from scikit-learn->biosppy) (3.5.0)
Requirement already satisfied: cffi>=1.0 in e:\users\dawid\anaconda3\lib\site-
packages (from soundfile>=0.10.0->wfdb) (1.17.1)
Requirement already satisfied: pycparser in e:\users\dawid\anaconda3\lib\site-
packages (from cffi>=1.0->soundfile>=0.10.0->wfdb) (2.21)
Downloading wfdb-4.3.0-py3-none-any.whl (163 kB)
Downloading biosppy-2.2.3-py2.py3-none-any.whl (158 kB)
Downloading neurokit2-0.2.11-py2.py3-none-any.whl (696 kB)
----- 0.0/696.5 kB ? eta -:-:-
----- 696.5/696.5 kB 27.1 MB/s eta 0:00:00
Downloading aiohttp-3.12.13-cp312-cp312-win_amd64.whl (447 kB)
Downloading pandas-2.3.0-cp312-cp312-win_amd64.whl (11.0 MB)
----- 0.0/11.0 MB ? eta -:-:-
----- 5.8/11.0 MB 27.0 MB/s eta 0:00:01
----- 11.0/11.0 MB 27.4 MB/s eta 0:00:00
Downloading bidict-0.23.1-py3-none-any.whl (32 kB)
Downloading mock-5.2.0-py3-none-any.whl (31 kB)
Downloading shortuuid-1.0.13-py3-none-any.whl (10 kB)
Downloading aiohappyeyeballs-2.6.1-py3-none-any.whl (15 kB)
Downloading propcache-0.3.2-cp312-cp312-win_amd64.whl (41 kB)
Downloading yar1-1.20.1-cp312-cp312-win_amd64.whl (86 kB)
Installing collected packages: shortuuid, propcache, mock, bidict,

```

```

aiohappyeyeballs, yarl, pandas, neurokit2, biosppy, aiohttp, wfdb
Attempting uninstall: aiohappyeyeballs
  Found existing installation: aiohappyeyeballs 2.4.0
  Uninstalling aiohappyeyeballs-2.4.0:
    Successfully uninstalled aiohappyeyeballs-2.4.0
Attempting uninstall: yarl
  Found existing installation: yarl 1.11.0
  Uninstalling yarl-1.11.0:
    Successfully uninstalled yarl-1.11.0
Attempting uninstall: pandas
  Found existing installation: pandas 2.2.2
  Uninstalling pandas-2.2.2:
    Successfully uninstalled pandas-2.2.2
Attempting uninstall: aiohttp
  Found existing installation: aiohttp 3.10.5
  Uninstalling aiohttp-3.10.5:
    Successfully uninstalled aiohttp-3.10.5
Successfully installed aiohappyeyeballs-2.6.1 aiohttp-3.12.13 bidict-0.23.1
biosppy-2.2.3 mock-5.2.0 neurokit2-0.2.11 pandas-2.3.0 propcache-0.3.2
shortuuid-1.0.13 wfdb-4.3.0 yarl-1.20.1

```

1.2.1 Step 1: Load/Simulate ECG Signal

```

[ ]: import numpy as np
import matplotlib.pyplot as plt
import neurokit2 as nk

sampling_rate = 500

# Simulate ECG signal
ecg = nk.ecg_simulate(duration=12, sampling_rate=sampling_rate, noise=0.05)
time = np.arange(len(ecg)) / 500 # Time axis in seconds

```

1.2.2 Step 2: Apply Bandpass Filter (1–50 Hz)

```

[ ]: from scipy.signal import butter, filtfilt

def bandpass_filter(signal, lowcut, highcut, fs, order=4):
    nyq = 0.5 * fs
    low = lowcut / nyq
    high = highcut / nyq
    b, a = butter(order, [low, high], btype='band')
    return filtfilt(b, a, signal)

filtered_ecg = bandpass_filter(ecg, 1.0, 50.0, sampling_rate)

```

1.2.3 Step 3: Detect R-Peaks

```
[ ]: # Detect R-peaks using NeuroKit2
_, rpeaks_info = nk.ecg_peaks(filtered_ecg, sampling_rate=500)
rpeaks = rpeaks_info["ECG_R_Peaks"]
```

1.2.4 Step 4: Compute and Plot Heart Rate

```
[4]: # Calculate R-R intervals and instantaneous heart rate (BPM)
rr_intervals = np.diff(rpeaks) / 500 # Convert to seconds
heart_rate = 60 / rr_intervals # BPM

# Time points for heart rate (midpoint between R-peaks)
hr_time = (rpeaks[1:] + rpeaks[:-1]) / (2 * 500)

# Plotting
plt.figure(figsize=(12, 10))

# Raw vs. Filtered ECG
plt.subplot(3, 1, 1)
plt.plot(time, ecg, label='Raw ECG', alpha=0.7)
plt.plot(time, filtered_ecg, label='Filtered ECG (1-50 Hz)', linewidth=1.5)
plt.plot(rpeaks/500, filtered_ecg[rpeaks], 'ro', label='R-peaks')
plt.title("ECG Signal with R-Peak Detection")
plt.xlabel("Time (s)")
plt.ylabel("Amplitude")
plt.legend()

# Heart Rate Over Time
plt.subplot(3, 1, 2)
plt.plot(hr_time, heart_rate, 'g-', marker='o', markersize=4)
plt.title("Instantaneous Heart Rate")
plt.xlabel("Time (s)")
plt.ylabel("BPM")
plt.grid(True)

# Zoomed ECG Segment
plt.subplot(3, 1, 3)
plt.plot(time[1000:2000], filtered_ecg[1000:2000], label='Filtered ECG')
plt.plot(rpeaks/500, filtered_ecg[rpeaks], 'ro', label='R-peaks')
plt.xlim(2, 4) # Zoom into 2-4 seconds
plt.title("Zoomed Segment (2-4s)")
plt.xlabel("Time (s)")
plt.ylabel("Amplitude")
plt.tight_layout()
plt.show()
```

