DOING PHYSICS WITH PYTHON

FOURIER METHODS

FOURIER TRANSFORMS

ELECTROCARDIOGRAPH ECG

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DOWNLOAD DIRECTORIES FOR PYTHON CODE

Google drive

GitHub

simFM004A ecg.mat

The Code are used to calculate the Fourier transform and the power spectral density functions by the direct integration of the Fourier integrals using Simpson's rule.

For a more in-depth discussion on the Fourier transform visit

FOURIER TRANSFORMS / GAUSSIAN FUNCTION

INTRODUCTION

Many physical processes can be described in the **time domain** by the values of a function $h(t)$ or else in the **frequency domain** $H(f)$. The function $H(f)$ is usually complex function specified by its amplitude and phase.

Fourier transform equations

$$(1) \qquad H(f) = \int_{-\infty}^{\infty} h(t) e^{i(2\pi f t)}\, dt$$

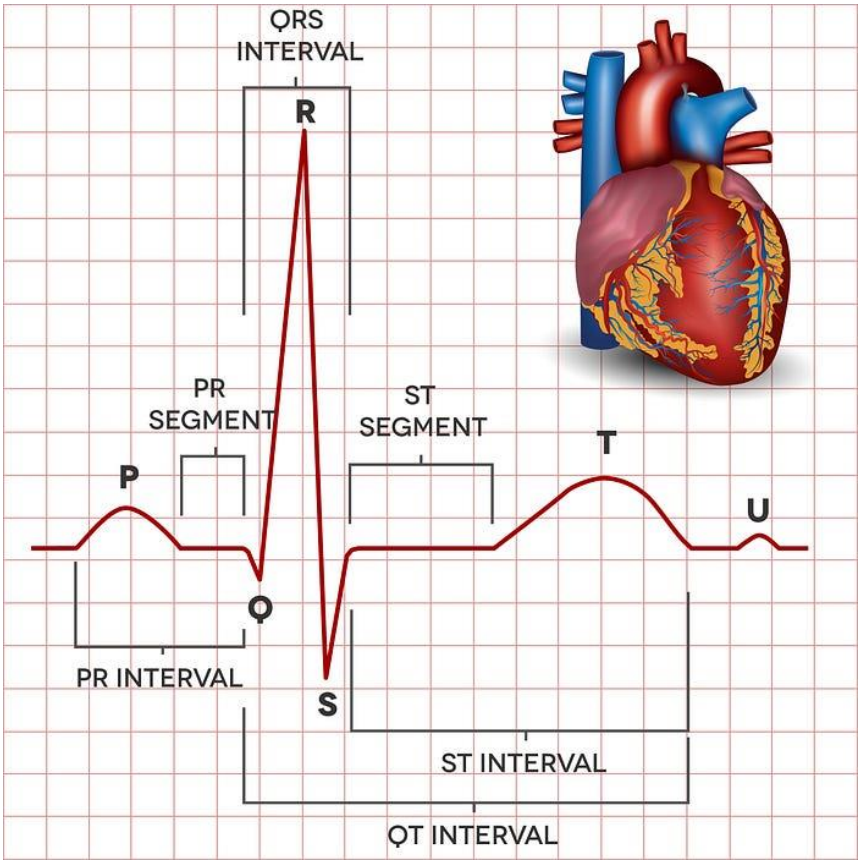
$$(2) \qquad h(t) = \int_{-\infty}^{\infty} H(f) e^{-i(2\pi f t)}\, df$$

Equation 1 is the **Fourier transform** and equation 2 gives the **inverse Fourier transform**. If t is measured in seconds, then the frequency f is measured in hertz and the angular frequency ω in radians.

ELECTROCARDIOGRAPH ECG

Source

In the time domain, a signal shows how a specific quantity, such as voltage or sound, changes over time. For example, the ECG, a composite signal where the amplitude represents the voltage generated by electrical impulses as the heart relaxes and contracts. Each heartbeat produces a characteristic waveform due to this electrical activity in the heart.



P wave - atrial depolarization, the electrical impulse triggering the atria to contract. Low frequency activity 0.5–10 Hz.

QRS complex - ventricular depolarization - the electrical impulse triggering the ventricles to contract. The largest and fastest electrical activity, often containing frequencies between 10–50 Hz.

T wave - ventricular repolarization - the recovery phase of the ventricles. Lower-frequency activities 0.5–10 Hz.

Noise: High-frequency noise (from muscle activity or electrical interference) can appear in the spectrum and be filtered out to focus on the relevant heart signal.

The frequencies and amplitudes of an ECG signal for a healthy human being depend on the individual's physiology and can vary slightly. The heart rate frequency (main signal), for most healthy adults is 55- 85 beats per minute (frequency 0.6 Hz - 2 Hz).

By applying Fourier analysis, we can decompose this signal into its individual frequency components to gain a deeper insight into heart health and rhythm abnormalities. The result of the Fourier Transform is a spectrum that shows the magnitude of each frequency component in the signal.

SIMULATION simFM004A.py

The following figures show a sample ECG recording and its Fourier transform. The ECG recording data is stored in the Matlab data file **ecg.mat**.

```
#%% TIME DOMAIN: Load the .mat file into a Python dictionary
ecg_data = scipy.io.loadmat('ecg.mat')
# Extract the ecg data
x = ecg_data['ecg']
# Time span [s]
t = linspace(0,18,len(x))
# ecg data function
h = x[:,0]

#%%  FREQUENCY DOMAIN
Nf = 3999
f1 = -19; f2 = 19
f = linspace(f1,f2,Nf)
p  = 1j*2*pi
HR = zeros(Nf); HI = HR; H = HR+HI*1j
# Fourier transform
for c in range(Nf):
    g = h*exp(p*f[c]*t)
    H[c] = simpson(real(g),t) + 1j*simpson(imag(g),t)
# one-sided power spectral density
psd = 2*abs(H)**2
```

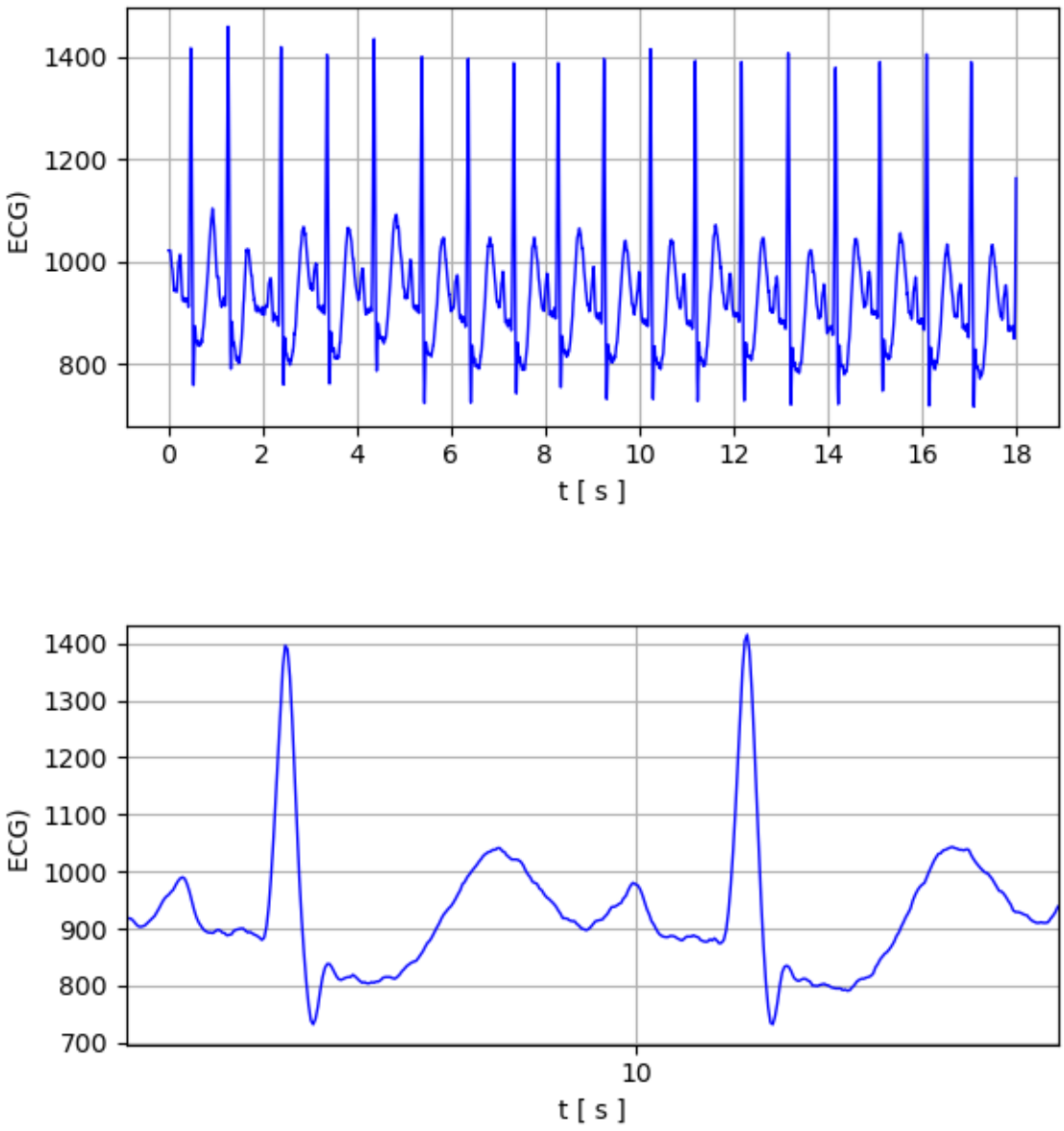


Fig. 1. ECG recording.

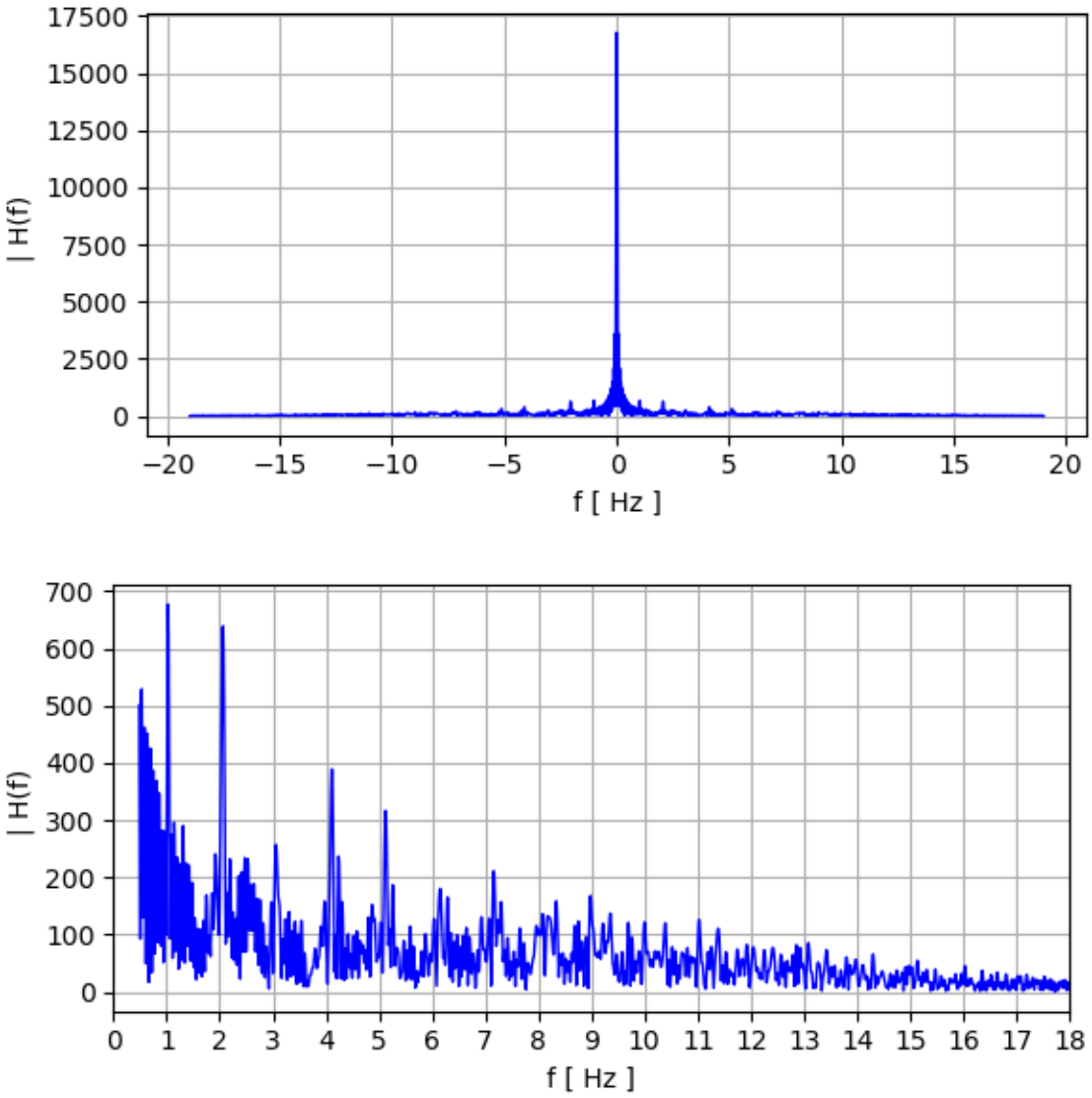


Fig. 2. Fourier transform of the ECG recording. Top graph shows a large DC peak. The bottom plot shows the Fourier transform for frequency greater zero.

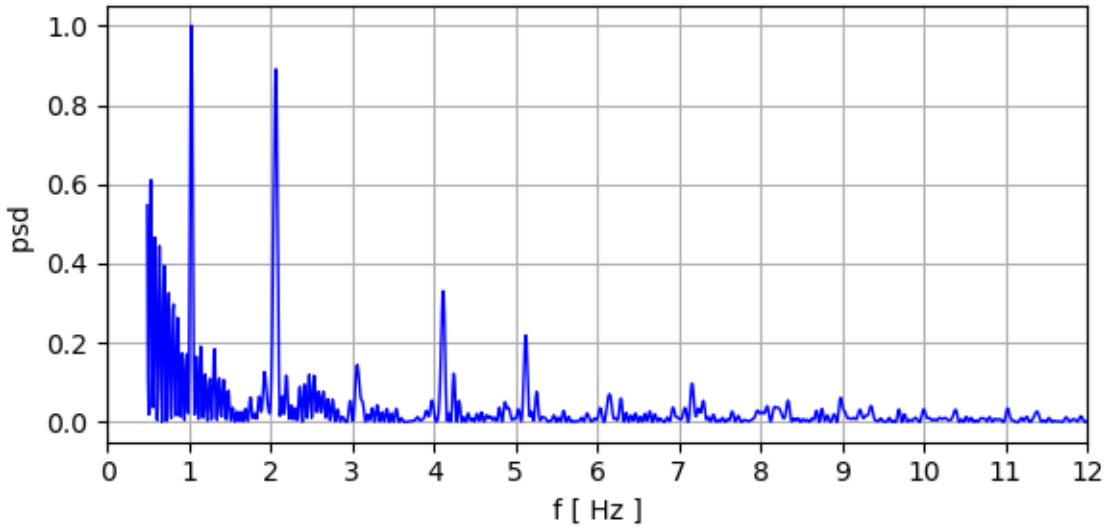


Fig. 3. The one-sided power spectral density plot.

Only the low frequency peaks (f < ~7 Hz) are predominant. The most significant peak occurs at f = 1 Hz and the second most significant peak at 2 Hz.