The objective of this exercise is that you analyse the code provided and make the link with the course. You have to provide a short report that comments and analyse the results. You can use directly the results or adapt them to you needs.

import the numerical library

```
import numpy as np
# import signal processing library
import scipy.signal as sp
# import ploting library
import pylab as py
py.ion()
py.close('all')
```

load the ecg signal

```
x = np.genfromtxt('accel.dat')
# sampling frequency of the signal is 500 Hz
fs = 40
# generate correponding time vector
t = np.arange(len(x))/fs
```

Plot time signal. Q: Comment the figure.

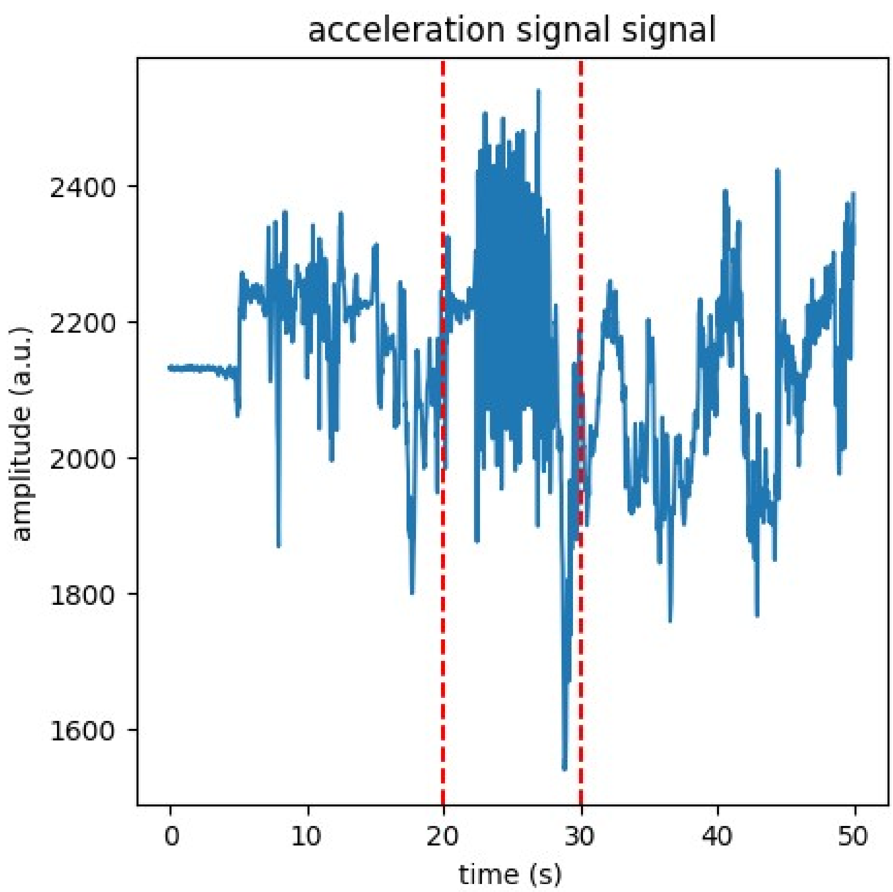
Compute the FFT of the signal

```
x_fft = np.fft.fft(x)
# Determine the frequency scale
f_fft = np.arange(len(x_fft))/len(x_fft)*fs
```

plot the signal

```
py.figure(1, figsize=[5,5])
py.clf()
py.plot(t, x)
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
# Put vertical lines btw 20 and 30 seconds (Handwashing),
discontinuous line
py.axvline(20, color='r', linestyle='--')
py.axvline(30, color='r', linestyle='--')
py.title('acceleration signal signal')
```

```
Text(0.5, 1.0, 'acceleration signal signal')
```



Answer

When plotting the signal, we can clearly observe fast movements in the 20-30 second range. This strongly suggests that the regular and repetitive movements during this period correspond to the hands rubbing against each other during hand-washing activity.

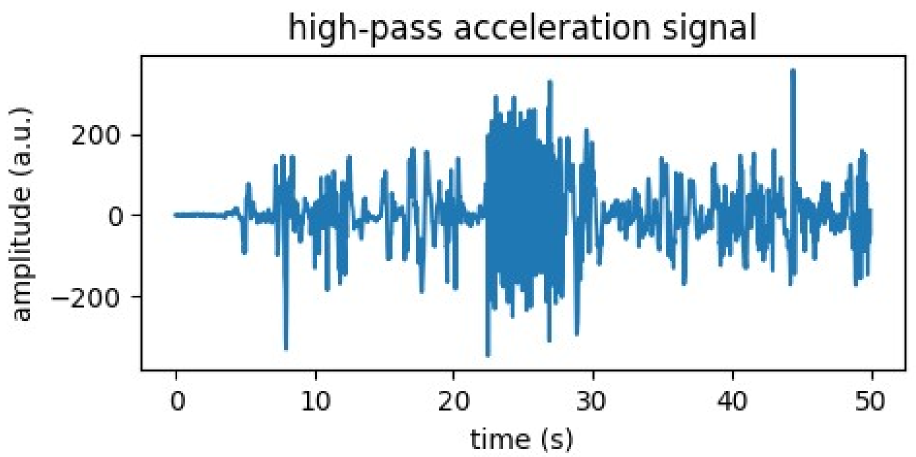
High pass the signal. Q: Comment the figure.

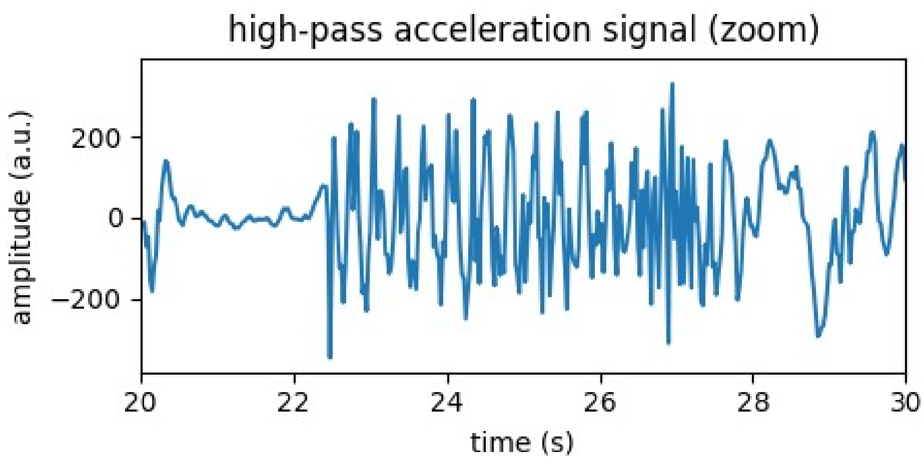
high-pass filter with cutoff frequency of 0.5 Hz

```
b, a = sp.butter(4, 0.5/fs*2, btype='high')
# zero-phase filtering of the signal
x_hp = sp.filtfilt(b, a, x)

py.figure(2, figsize=[5,5])
py.clf()
py.subplot(2,1,1)
py.plot(t, x_hp)
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
py.title('high-pass acceleration signal')
py.subplot(2,1,2)
py.plot(t, x_hp)
```

```
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
py.title('high-pass acceleration signal (zoom)')
py.xlim(20, 30)
# Adjust to the figure to show it properly
py.tight_layout()
```





Answer

By applying a high-pass filter with a cutoff frequency of 0.5 Hz, we reduce the impact of low-frequency components, resulting in a clearer trend between 20 and 30 seconds. And zooming in on the filtered signal, we can more clearly identify the hand-washing activity with a significantly change in the signal. It suggests that the frequencies of the handwashing is slightly higher in frequency than this 0.5 Hz.

Band pass the signal between 2.4 and 3.2 Hz. Q: Based on previous figure, comment the selection of the frequencies. Q: Why zero phase filter (filtfilt) is used?

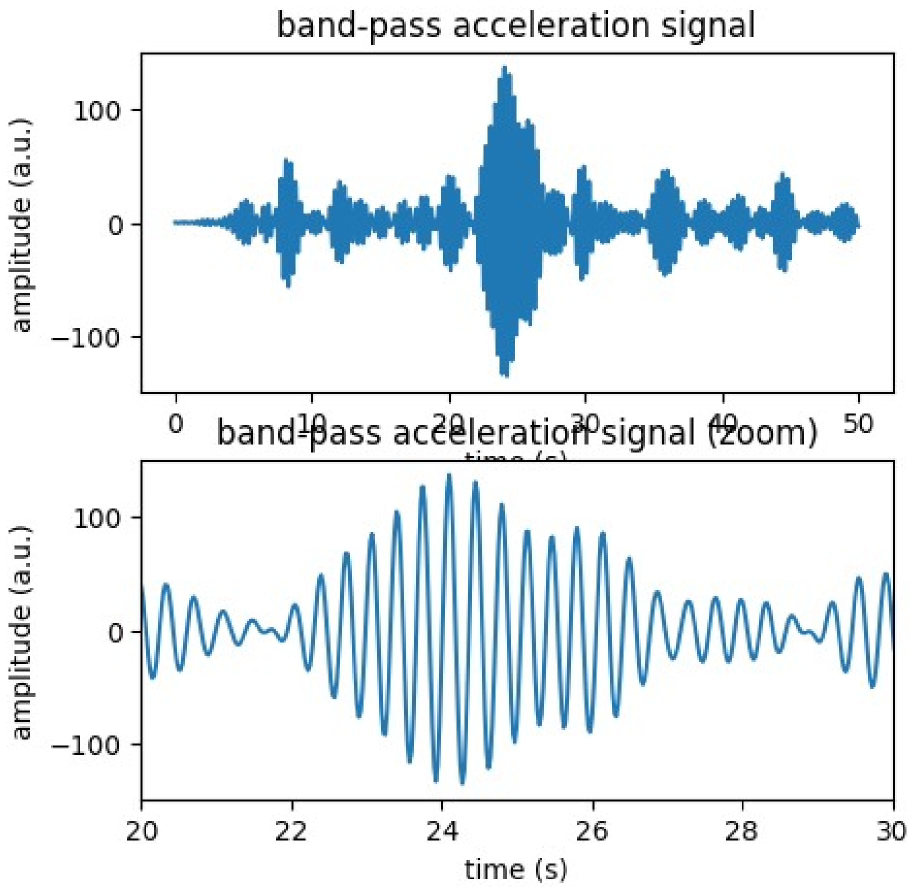
Analogic limit of the passband frequency

```python
f_pass = np.array([2.4, 3.2])
# Analogic limit of the stopband frequency
f_stop = np.array([0, 5])
# Convertion into Nyquist frequency
f_pass_N = f_pass/fs*2
f_stop_N = f_stop/fs*2
# Max attenutation in passband (dB)
g_pass = 3
# Min attenuation in stopband (dB)
g_stop = 40
# Determine the order and the cutoff frequency of a butterworth filter
ord, wn = sp.buttord(f_pass_N, f_stop_N, g_pass, g_stop)
# Compute the coeffcients of the filter
b, a = sp.butter(ord, wn, btype='band')
# Filter the signal
x_bp = sp.filtfilt(b ,a, x_hp)
```

```
/usr/local/anaconda3/envs/ABSP/lib/python3.12/site-packages/scipy/
signal/_filter_design.py:3868: RuntimeWarning: divide by zero
encountered in divide
  nat = ((stopb ** 2 - passb[0] * passb[1]) /
```

```python
py.figure(3, figsize=[5,5])
py.clf()
py.subplot(2,1,1)
py.plot(t, x_bp)
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
py.title('band-pass acceleration signal')
py.subplot(2,1,2)
py.plot(t, x_bp)
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
py.title('band-pass acceleration signal (zoom)')
py.xlim(20, 30)
```

```
(20.0, 30.0)
```



Answer

We removed the frequencies outside the range of 2.4 and 3.2 Hz using a band-pass filter, which reduced the number of frequencies in the signal and highlighted those associated with hand-washing. The oscillations are more regular and clearly show the hand-washing movements, especially between 22 and 26 seconds.

A zero-phase filter was used, as in Lab 2, to avoid introducing phase delay into the filtered signal. Using a standard filter usually adds a phase shift (as seen in Lab 2 too), which can distort the desired signal and reduce accuracy

Low-pass filter of the power of the band-pass signal. Q: Why use the power of the acceleration signal? Q: How the detection of hand washing is obtained?

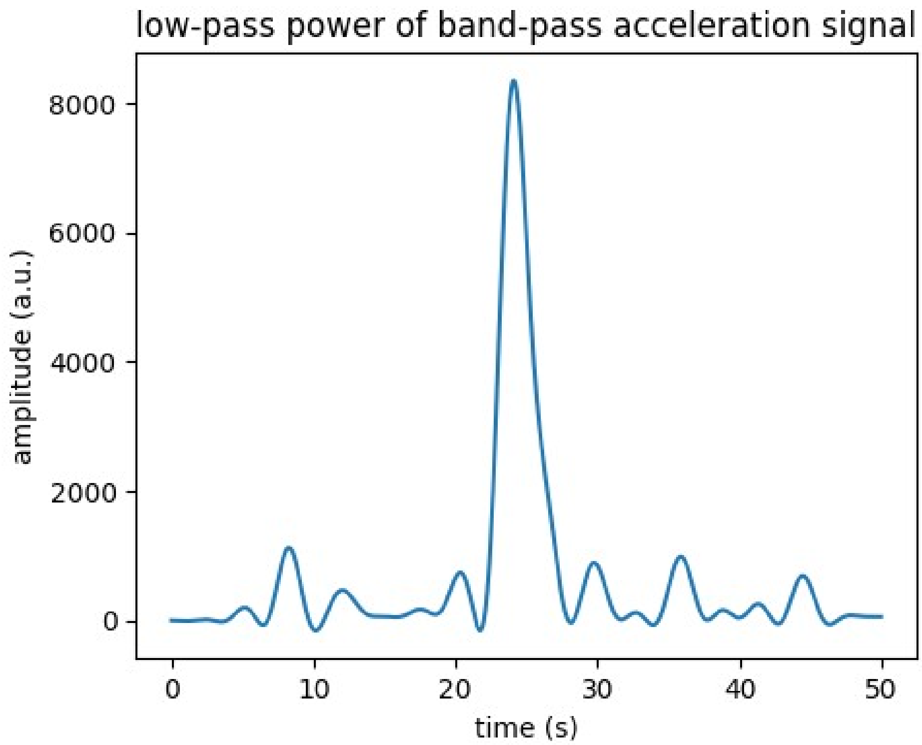
Analogic limit of the passband frequency

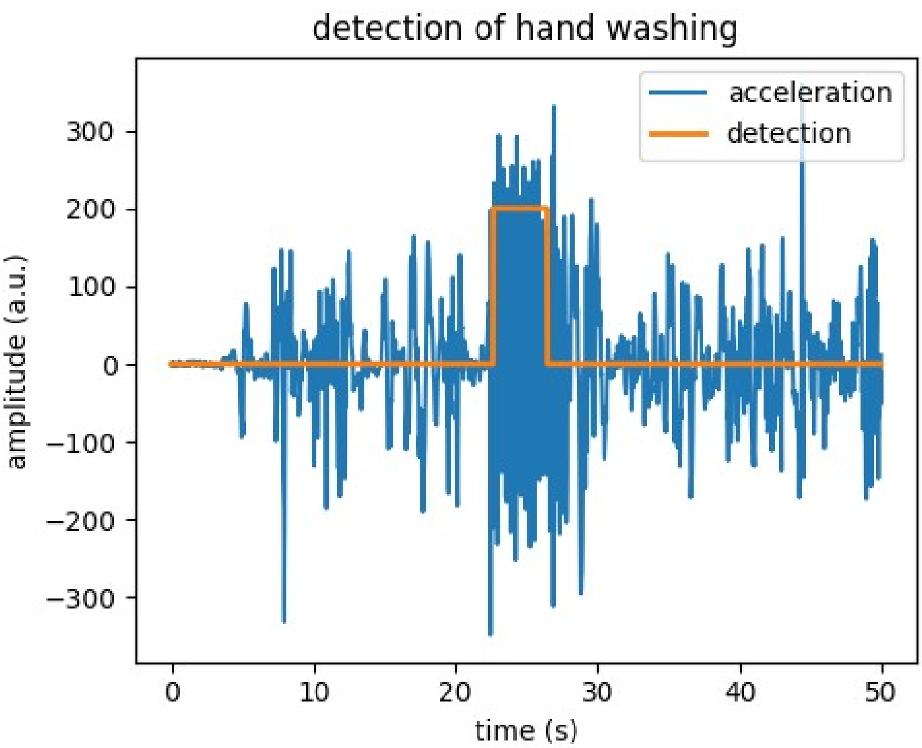
```
f_pass = 0.4
# Analogic limit of the stopband frequency
f_stop = 0.8
# Convertion into Nyquist frequency
f_pass_N = f_pass/fs*2
f_stop_N = f_stop/fs*2
# Max attenutation in passband (dB)
```

```
g_pass = 3
# Min attenuation in stopband (dB)
g_stop = 40
# Determine the order and the cutoff frequency of a butterworth filter
ord, wn = sp.buttord(f_pass_N, f_stop_N, g_pass, g_stop)
# Compute the coeffcients of the filter
b, a = sp.butter(ord, wn)
# Filter the signal
x_pow = sp.filtfilt(b ,a, x_bp**2)
# detection
det = x_pow > 2000

py.figure(4, figsize=[5,8])
py.clf()
py.subplot(2,1,1)
py.plot(t, x_pow)
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
py.title('low-pass power of band-pass acceleration signal')
py.subplot(2,1,2)
py.plot(t, x_hp, label='acceleration')
py.plot(t, det*200, linewidth=2, label='detection')
py.xlabel('time (s)')
py.ylabel('amplitude (a.u.)')
py.title('detection of hand washing')
py.tight_layout()
py.legend(loc='upper right')
```

```
<matplotlib.legend.Legend at 0x1201613a0>
```





Answer

The power of the acceleration signal $\left(x_{bp}^2\right)$ is used to accentuate the energy of the signal. Since the power is the squared magnitude, that is highlighting the larger peaks and reducing the smaller ones, hence in this case it's accentuating our handwashing movement, and minimizing the other frequencies. Using the power allows us to detect the handwashing movements more clearly.

After applying the low-pass filter on the signal obtained by band-pass filter, as explained above, we reduced the impact of smaller peaks and increase the more significant ones. We see that there is a clear and abrupt change in movement detection and we can deduce that is our handwashing movement (around 22s, shown with orange line) which is coeherent with what we discuss until this point. This technique permits to increase accurate handwashing detection.