University of Brasília

Electrical Engineering Department

Topics in Biomedical Engineering

Task 5

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1 Subject f2o02 - Elderly Subject

1.1 Signal Preprocessing

Before using the CRSIDLab, it's necessary to treat the data downloaded from the database of PhysioNet [1], to create the variables used in the toolbox, in this case, **ecg** and **bp** variables, time axis and sampling frequency. Furthermore, it's necessary to restrict the interval between five minutes (300 seconds), and, in this subjects, the interval between 2100 and 2400 seconds (minute 35 and minute 40) has little noise and generates a good observation around electrocardiogram and blood pressure signals. Thus, the **interval 2100 to 2400** seconds was the observed interval.

The MATLAB's code of the preprocessing of the subject **f2o02** ECG (electrocardiogram) and BP (blood pressure) signals:

```
%% data preprocessing
clc; clear all; close all;
warning('off');

% obs.: only 60 Hz filter

% subject f2o02
load f2o02m.mat;
fs2 = 250; % Hz
ts2 = 1/fs2;

% ECG
ecg = val(2,:);
base = 0; gain = 409.6; ecg = (ecg-base)./gain;

% BP
bp = val(3,:);
base = 0; gain = 409.6; bp =(bp-base)./gain;

% TIME CONVERSOR
% time vector for 5 min = 300 sec
% downloaded 1h of data from PhysioNet
tts = (60*60); % 1h00
tts_5min = (5*60);
```

```
n_points = length(ecg); % == length(bp) -¿ verified

% POINTS CONVERSOR
% to calculate the number of points in 300sec
% proportion:
% tts -- n_points
% 300 -- n_points_5min
n_points_5min = ((n_points*tts_5min)-1)/tts;

t_points = ((7*n_points_5min:8*n_points_5min) * ts2); % time vector

%% ECG plot
% ECG during 300 seconds
ecg = ecg(7*n_points_5min:8*n_points_5min); % 2100 - 2400 seg

% uncomment to see the plot if necessary
figure(1);
plot(t_points, ecg, 'r'); grid;
xlabel('Tempo (s)');
ylabel('ECG (mV)');
title('f2o02 - ECG x Tempo');

%% BP plot
% BP during 300 seconds
bp = bp(7*n_points_5min:8*n_points_5min); % 2100 - 2400 seg

% uncomment to see the plot if necessary
figure(2);
plot(t_points, bp, 'b'); grid;
xlabel('Tempo (s)');
ylabel('BP (mV)');
title('f2o02 - BP x Tempo');
```

As shown in the Figure 1, the ECG signal of the eldery subject has some noise in the low amplitude regions, mainly on P-wave and T-wave. In front of that, it's necessary to apply a filtering process to get the signal more satisfying.

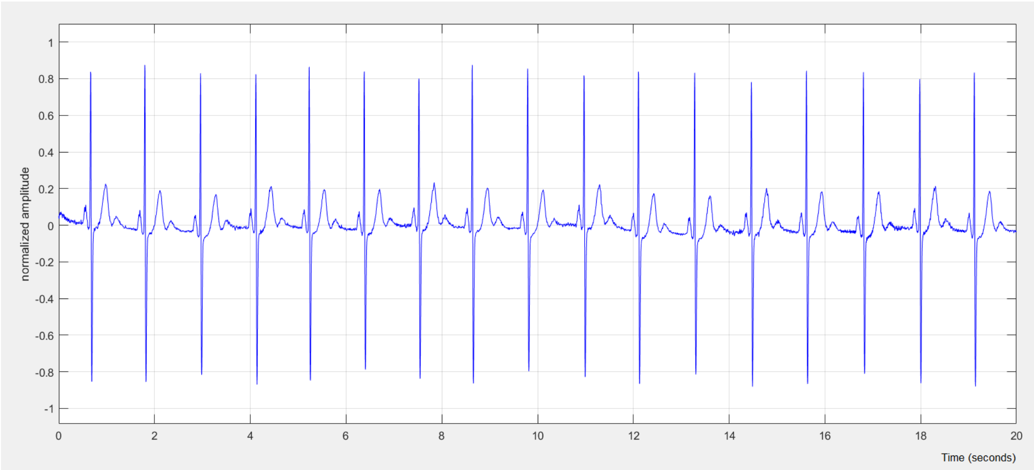

Figure 1: ECG signal of the elderly subject filtered.

The filtering process depends on each situation and depends of the objective of the analysis in question. It is recommendable to use filters only if necessary, since unnecessary interference can be introduced to the original signal. In this case of the ECG signal of the elderly subject, the **Notch Filter** was applied with the width of 1% (default), that is a 60 Hz filter applied in order to remove possible interference from the frequency of the 60 Hz electrical network in Brazil. The filters HF Noise and Baseline Wender were tested, but they did not make relevant improvements and, therefore, they were not applied.

In the same way, the filters did not make relevant improvements in the BP signal, and they were not applied either.

These filter applying commands are shown in the Figure 2.

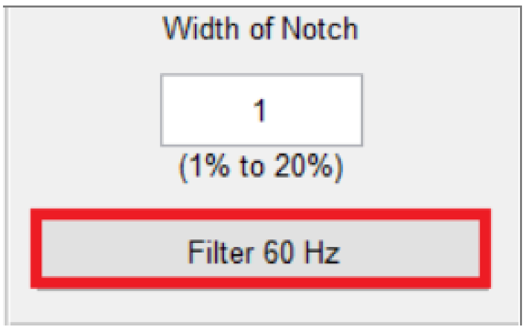

Figure 2: Steps: 1. Notch Filter.

In sequence, it is necessary to select the **Filtered ECG data** to mark to R peaks, as shown in the Figure 3.

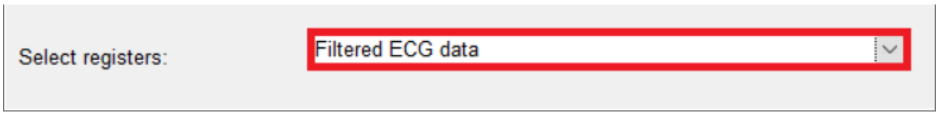

Figure 3: Command to select the filtered signal.

The mark process of the R peaks in the ECG signal is **always** shown and follows the **Slow Algorithm**, that is a non-technique algorithm, but is a name chosen during the CRSIDLab creation. This step-by-step is exposed below:

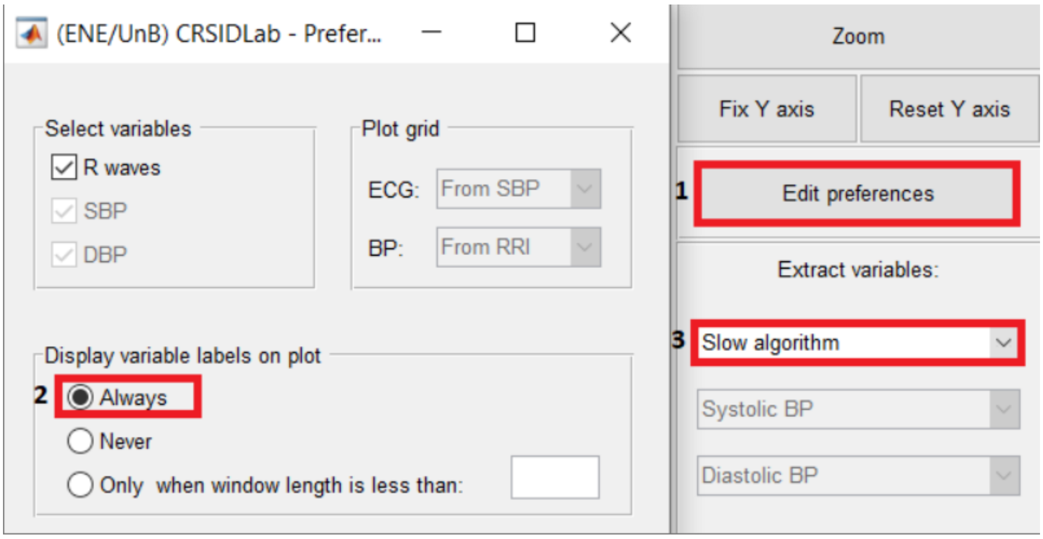

Figure 4: Step-by-step to mark R peaks.

Furthermore, it is necessary to mark the SBP (systolic blood pressure) and DBP (diastolic blood pressure) peaks of the BP signal. This process is done marking **From RRI** and **From RRI & SBP** respectively, as shown in the Figure 5.

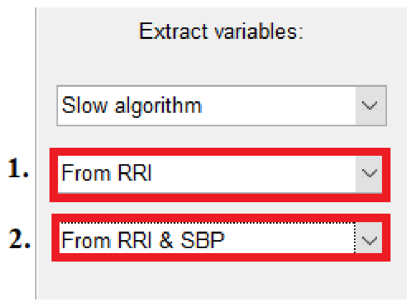

Figure 5: Step-by-step to mark SBP e DBP peaks.

During all the 300 seconds, the visualization is compromised. Thus, the Figure 6 shows the R peaks (ECG signal) and SBP/DBP peaks (BP signal) marked during 20 seconds, more specifically, from the second 0 to the second 20. Notably generating a better view of R peaks and, RR interval (RRi) and SBP/DBP data.

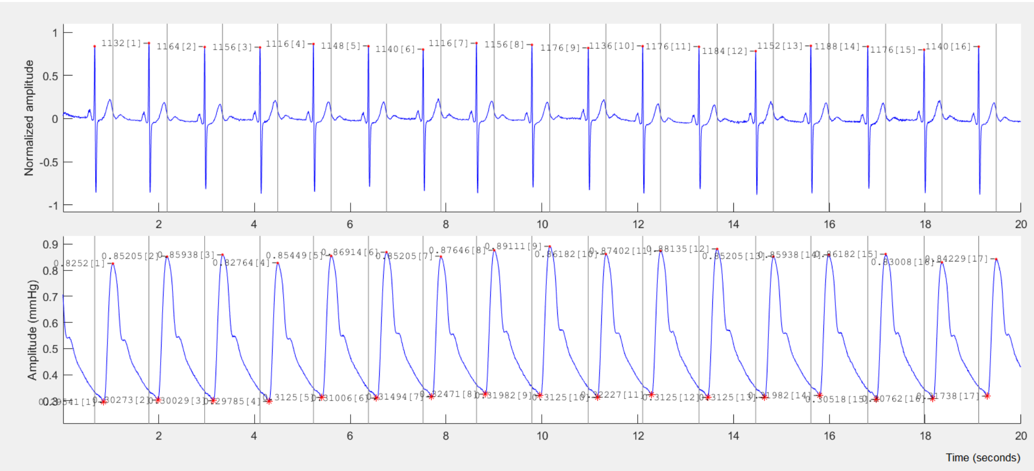

Figure 6: R peaks and SBP/DBP peaks of the elderly subject during 20 seconds.

During this 5 minutes (minute 35 to minute 40), there is no ectopic beat. Thus, this marking process was unnecessary.

Finally, the data had to be aligned and resampled. The RRi and the SBP data were selected (Figure 7):

Figure 7: Selecting RRi and SBP data.

The resampling method used was **Berger Algorithm** and the sampling frequency used was $f = 4$ Hz. Other parameters were used accordingly to the default parameters of CRSIDLab, as shown in the Figure 9.

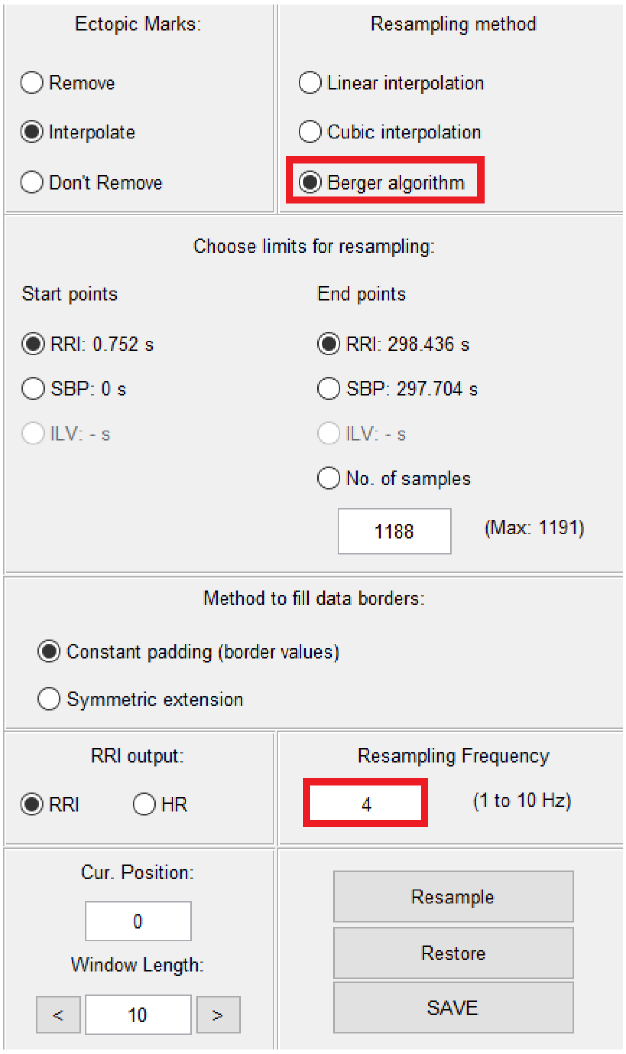

Figure 8: Steps of resampling and interpolation.

After this data preprocessing, the data had to be analyzed. More precisely, the Power Spectrum Density (PSD) of RRi and of the SBP had to be generated.

The window - in order to minimize spread spectrum - applied was the **Hanning** (suggested in the CRSIDLab tutorial), and other parameters were maintained as default.

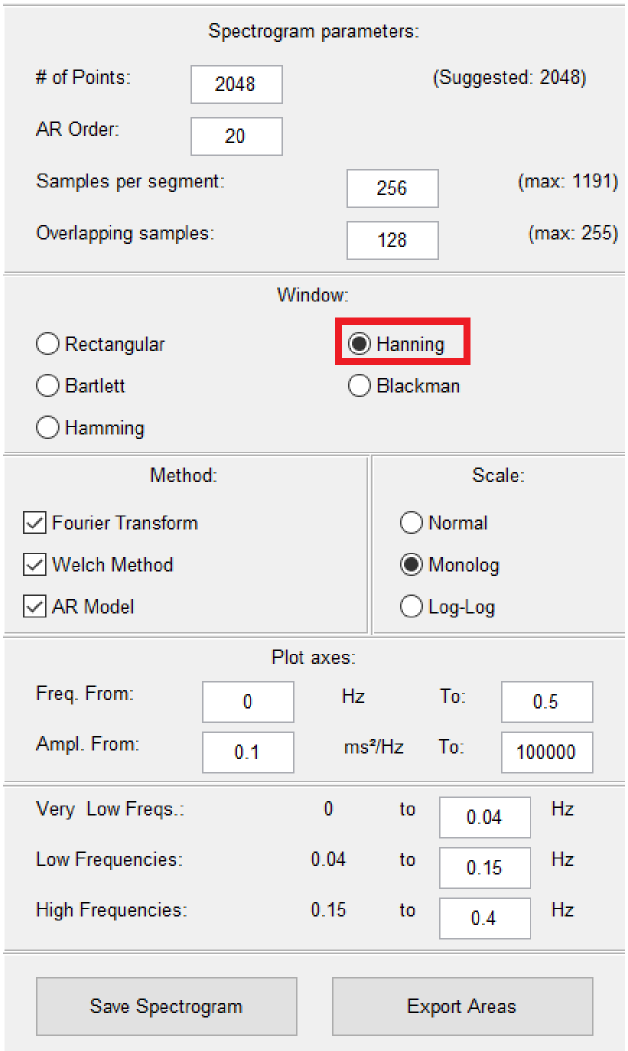

Figure 9: Applying the window.

Then, finally, the PSD were obtained automatically to the three methods (1. Fourier, 2. Welch and 3. AR Model).

1.2 Power Spectrum Density (PSD) of RRi

1.2.1 Welch

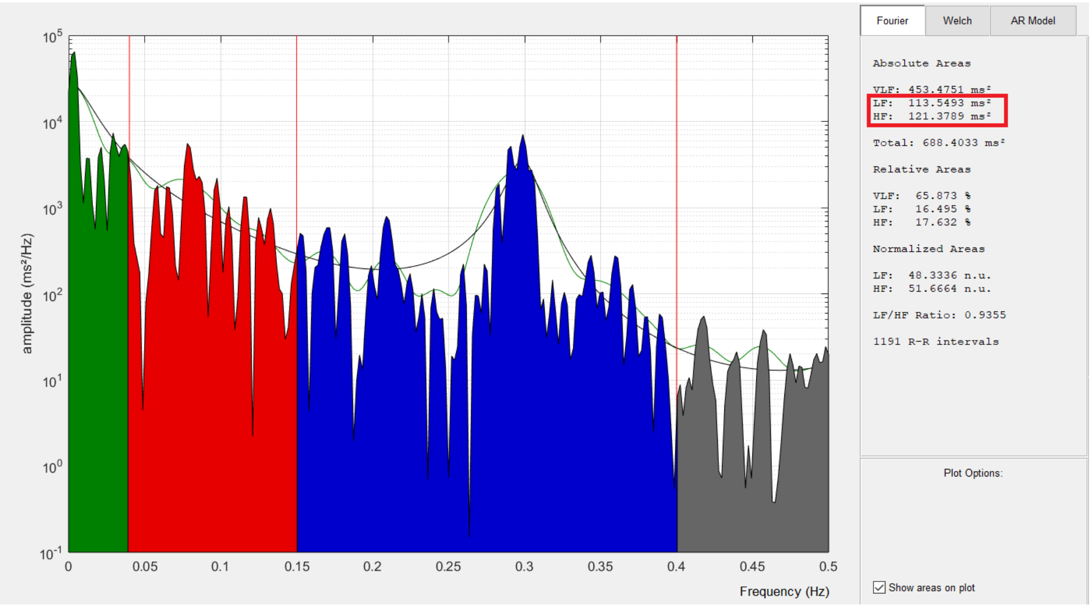

Figure 10: PSD of RRi - Fourier Method (Elderly Subject).

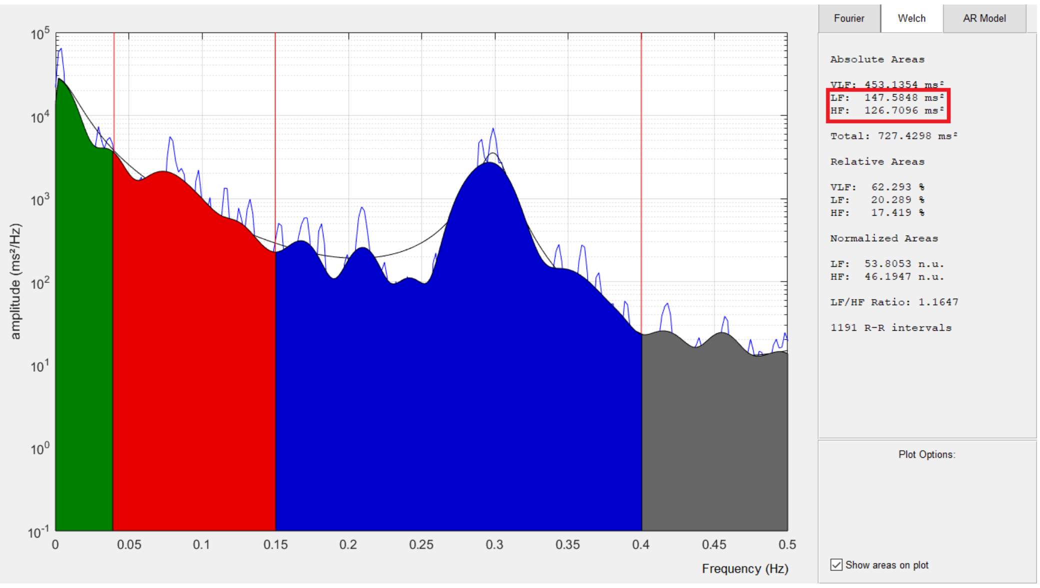

Figure 11: PSD of RRi - Welch Method (Elderly Subject).

1.2.2 AR Model

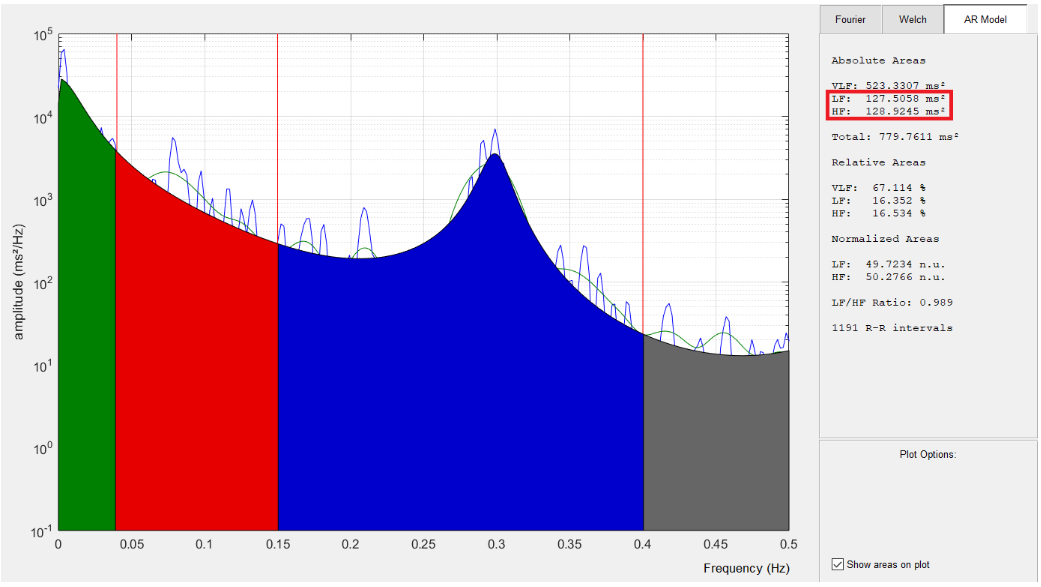

Figure 12: PSD of RRi - AR Model (Elderly Subject).

1.3 Power Spectrum Density (PSD) of SBP

1.3.1 Fourier

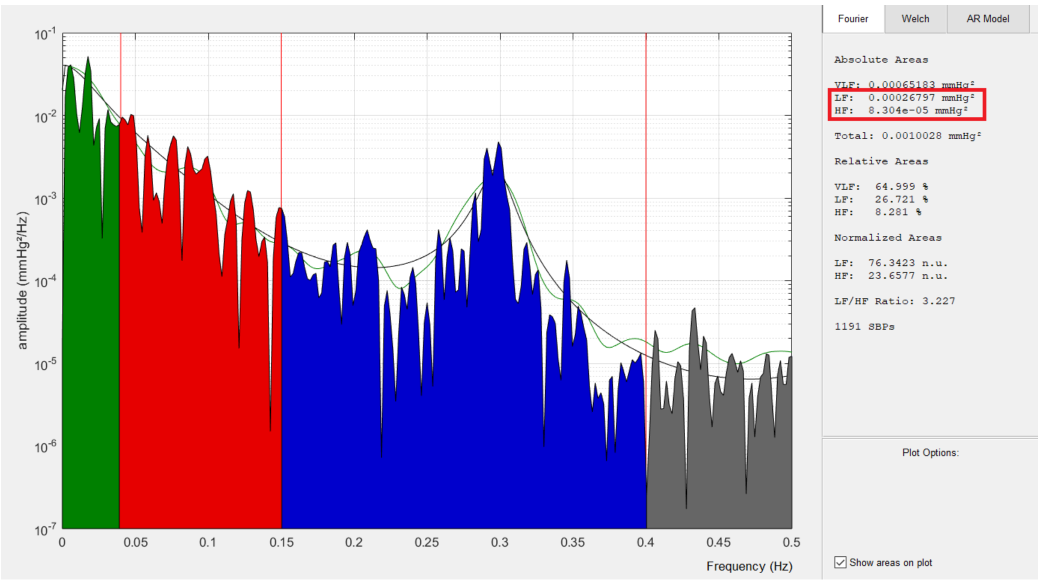

Figure 13: PSD of SBP - Fourier Method (Elderly Subject).

1.3.2 Welch

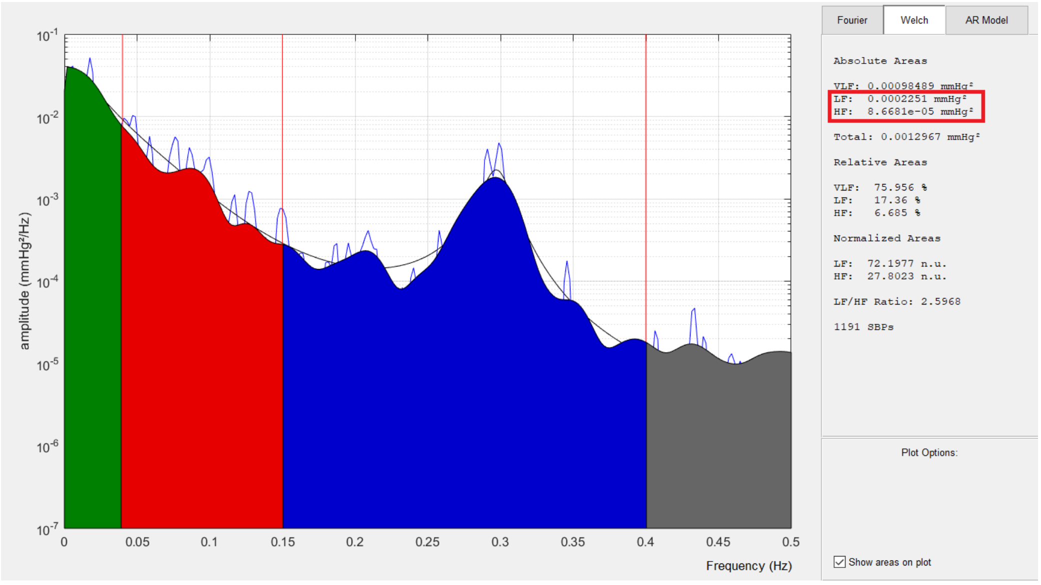

Figure 14: PSD of SBP - Welch Method (Elderly Subject).

1.3.3 AR Model

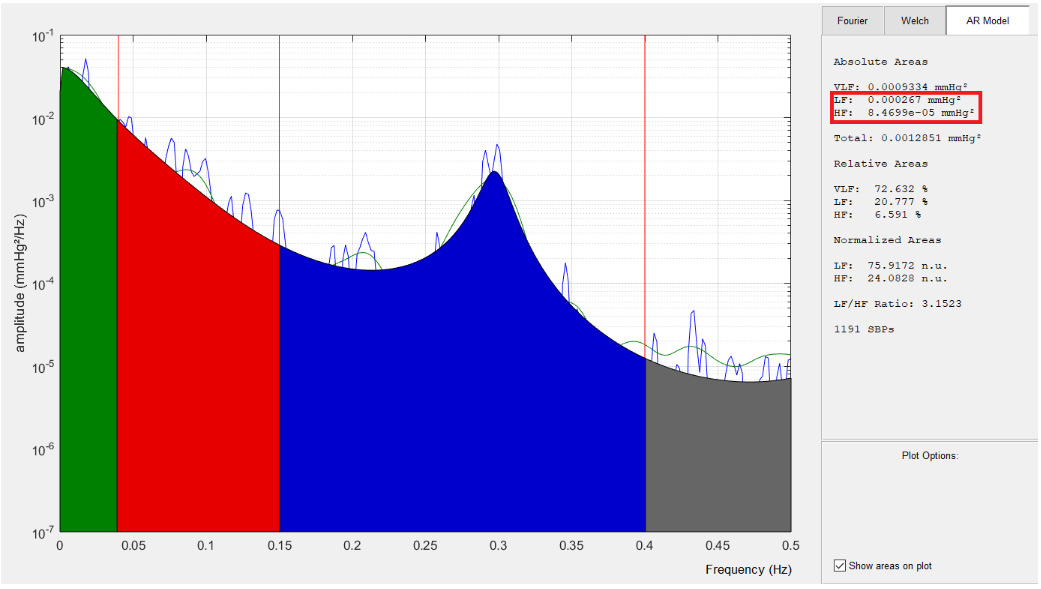

Figure 15: PSD of SBP - AR Model (Elderly Subject).

2 Subject f2y02 - Young Subject

2.1 Signal Preprocessing

Using the same time interval (second 2100 to second 2400) of the elderly subject, the MATLAB's code of the preprocesing of the subject **f2y02** ECG (electrocardiogram) and BP (blood pressure) signals:

```
%% data preprocessing
clc; clear all; close all;
warning('off');

% obs.: not necessary to apply filters

% subject f2y02
load f2y02m.mat;
fs = 333; % Hz
ts = 1/fs;

% ECG
ecg = val(2,:);
base = 0; gain = 819.2; ecg = (ecg-base)./gain;

% BP
bp = val(3,:);
base = 0; gain = 819.2; bp =(bp-base)./gain;

% TIME CONVERSOR
% time vector for 5 min = 300 sec
% downloaded 1h (50min3sec) of data from PhysioNet
tts = (50*60) + 3; % 50m e 3s
tts_5min = (5*60);
n_points = length(ecg);

% POINTS CONVERSOR
% to calculate the number of points in 300sec
% proportion:
% tts -- n_points
% 300 -- n_points_5min
n_points_5min = ((n_points*tts_5min)-1)/tts; % numero
```

```
    de pontos

t_points = ((7*n_points_5min:8*n_points_5min) * ts); % time vector

%% ECG plot
ecg = ecg(7*n_points_5min:8*n_points_5min); % 2100 - 2400 seg

% uncomment to see the plot if necessary
plot(t_points, ecg, 'r'); grid;
xlabel('Tempo (s)');
ylabel('ECG (mV)');
title('f2y02 - ECG x Tempo');

%% BP plot
% BP during 300 seconds
bp = bp(7*n_points_5min:8*n_points_5min); % 2100 - 2400 seg

% uncomment to see the plot if necessary
figure(2);
plot(t_points, bp, 'b'); grid;
xlabel('Tempo (s)');
ylabel('BP (mV)');
title('f2y02 - BP x Tempo');
```

During the preprocessing of the signal of the young subject, it was not necessary to use filters.

The process of mark the R peaks (ECG signal) and mark the SBP/DBP peaks (BP signal) was done following the same described in the elderly subject.

Therefore, the Figure 16 shows the R peaks (ECG signal) and SBP/DBP peaks (BP signal) marked during 20 seconds, more specifically, from the second 0 to the second 20. Notably generating a better view of R peaks and, RR interval (RRi) and SBP/DBP data.

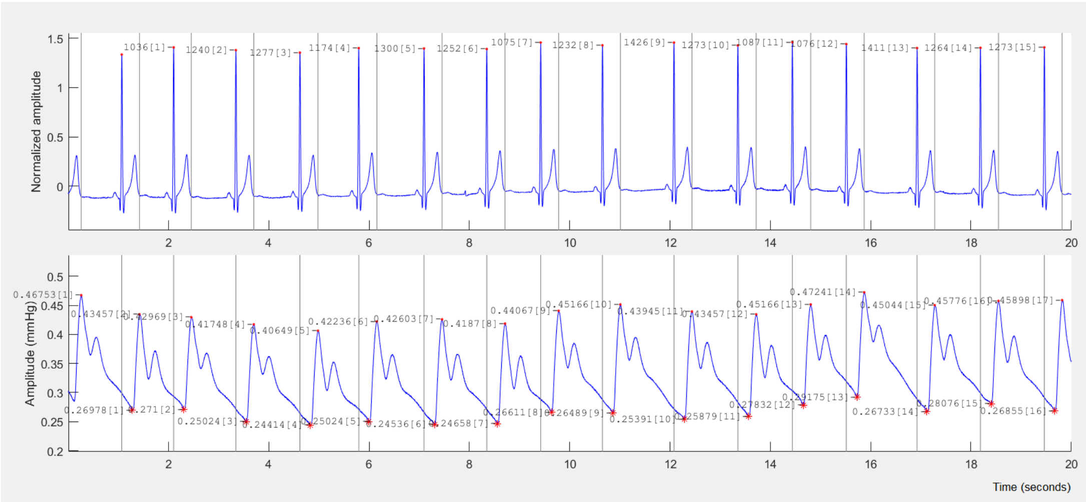

Figure 16: R peaks and SBP/DBP peaks of the young subject during 20 seconds.

During these 5 minutes (minute 35 to minute 40), there is no ectopic beat. Thus, this marking process was unnecessary.

The data had also to be aligned and resampled. The RRi and the SBP data were selected. The resampling method used was **Berger Algorithm** and the sampling frequency used was $f = 4$ Hz. Others parameters were used according to the default parameters of CRSIDLab. As mentioned above, these processes were the same adopted in the elderly subject (more details were described in the section 1.)

After this data preprocessing, the data had to be analyzed. More precisely, the Power Spectrum Density (PSD) of RRi and of the SBP had to be generated.

The window - in order to minimize spread spectrum - applied was the **Hanning** (sugested in the CRSIDLab tutorial), and other parameters were maintened as default. Then, finally, the PSDs were obtained automatically to the three methods (1. Fourier, 2. Welch and 3. AR Model).

2.2 Power Spectrum Density (PSD) of RRi

2.2.1 Fourier

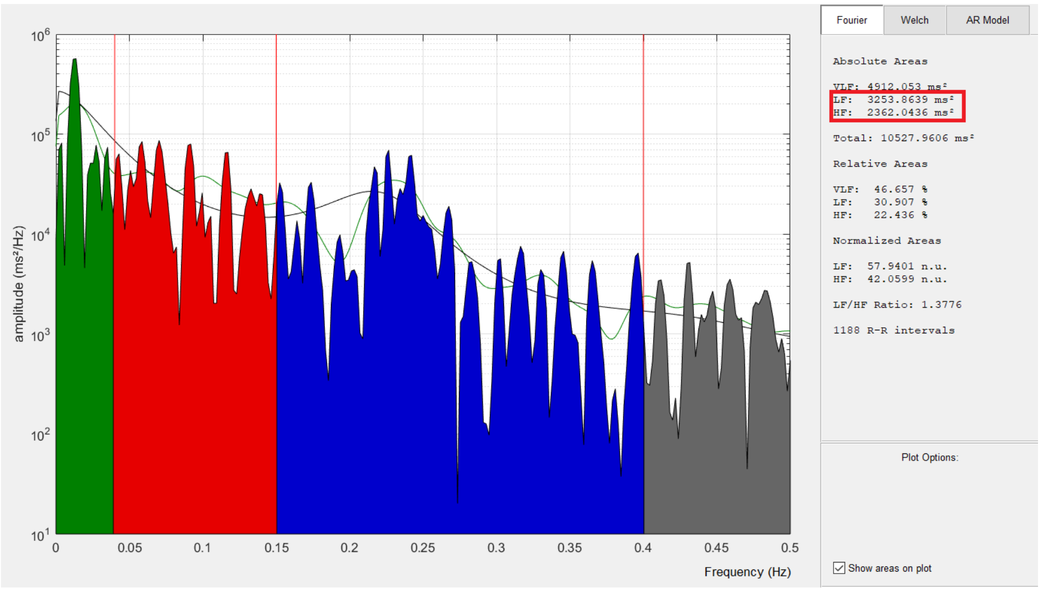

Figure 17: PSD of RRi - Fourier Method (Young Subject).

2.2.2 Welch

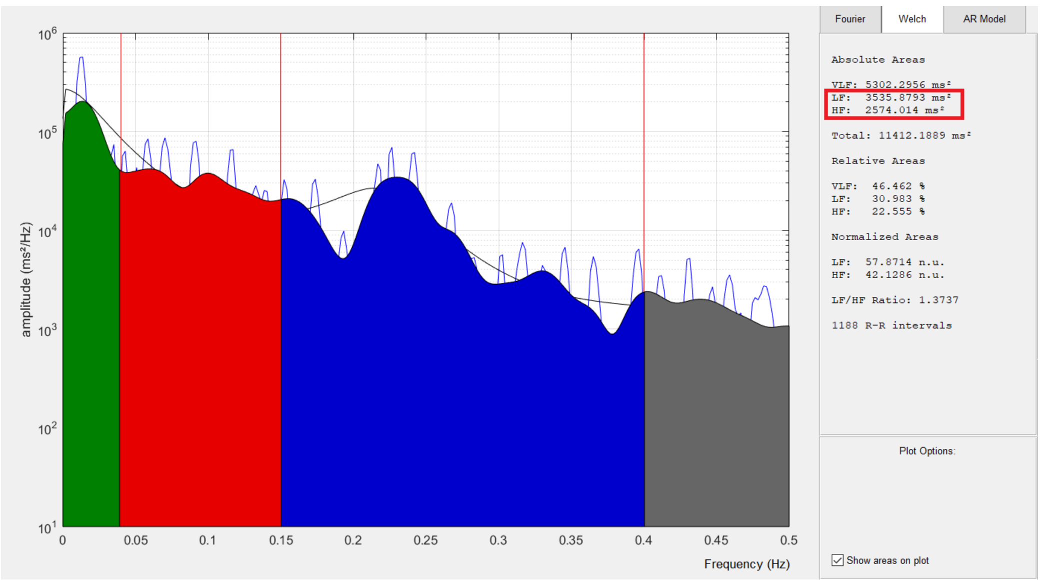

Figure 18: PSD of RRi - Welch Method (Young Subject).

2.2.3 AR Model

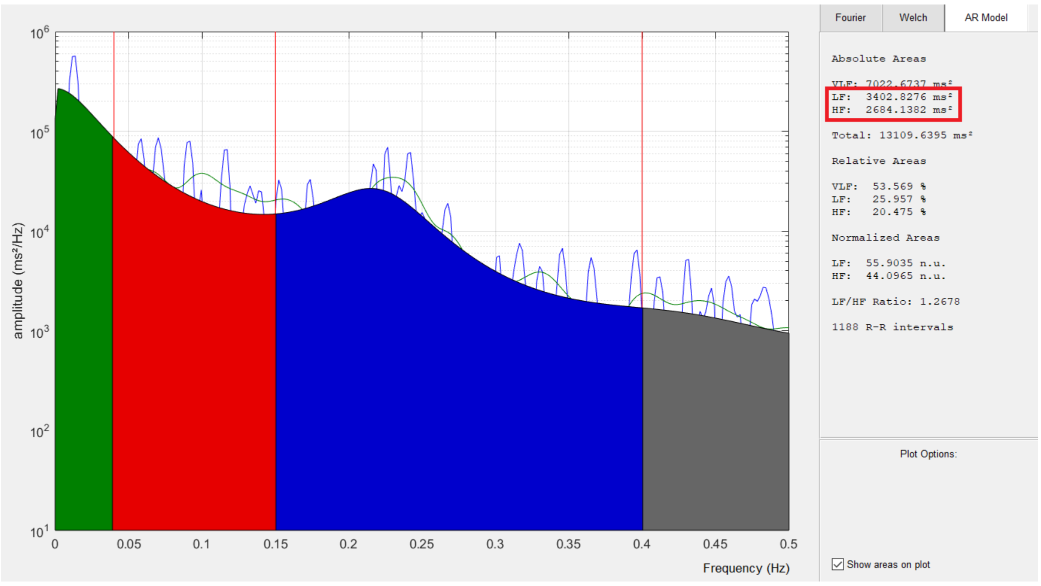

Figure 19: PSD of RRi - AR Model (Young Subject).

2.3 Power Spectrum Density (PSD) of SBP

2.3.1 Fourier

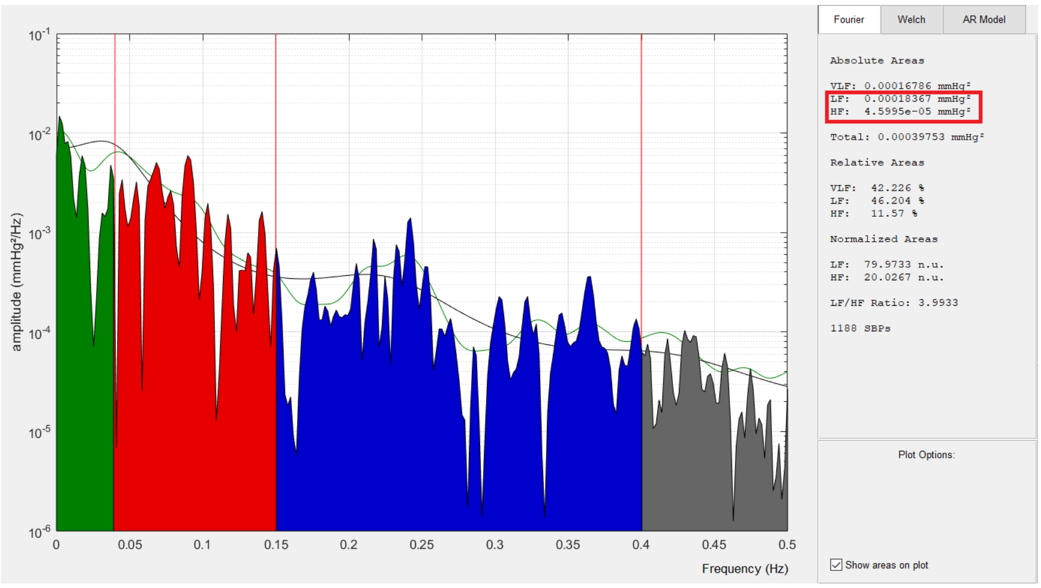

Figure 20: PSD of SBP - Fourier Method (Young Subject).

2.3.2 Welch

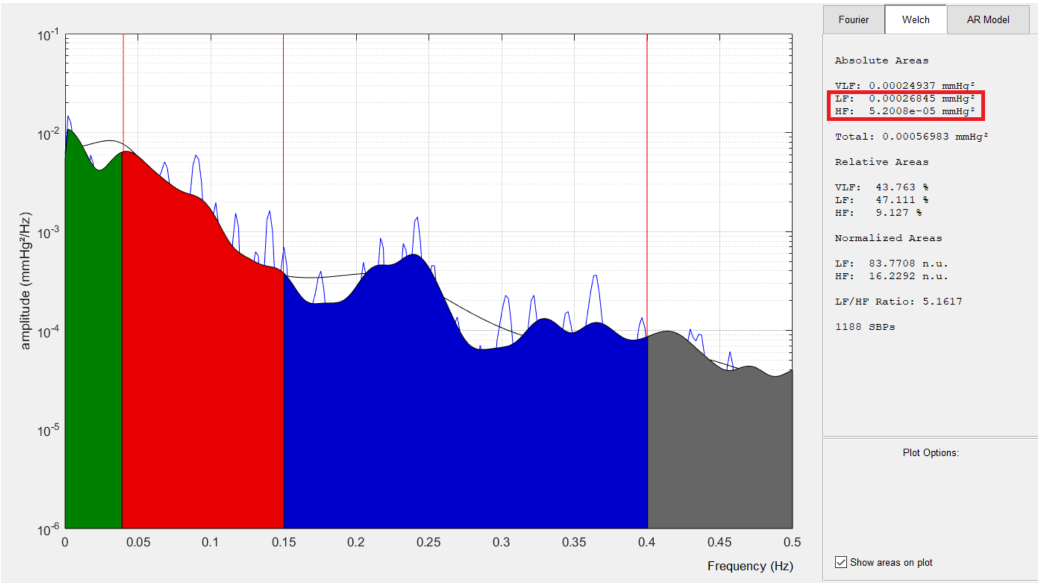

Figure 21: PSD of SBP - Welch Method (Young Subject).

2.3.3 AR Model

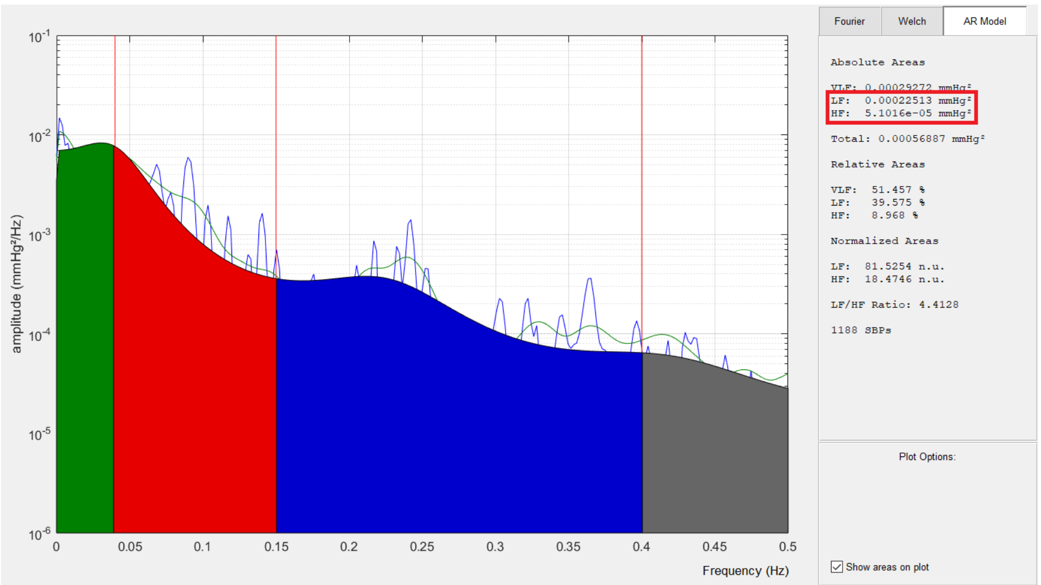

Figure 22: PSD of SBP - AR Model (Young Subject).

References

[1] "PhysioBank ATM." https://archive.physionet.org/cgi-bin/atm/ATM?database=fantasia&tool=plot_waveforms.