Sistema de filtragem

```
clearvars
```

Recolha de dados

```
filename = "domingues1_coxis.csv";
data_table = readtable(filename,"VariableNamingRule","preserve");
data_set_z = table2array(data_table(:,"z_accel"));
data_time = table2array(data_table(:,"Hours:Minutes:Seconds.Milliseconds"));
data_time = seconds(data_time); data_time = data_time - data_time(1);

% bitalino_Fs = 100;
% data_table = readtable("domingues_coxis_03.txt");
% data_set_z = table2array(data_table(:,"Var6"));
% data_time = linspace(0,length(data_set_z)/bitalino_Fs,length(data_set_z))';
```

Frequência

```
L = length(data_time);

Fs = mean(1./diff(data_time));
disp("Sampling rate: " + Fs + "Hz")
```

```
Sampling rate: 61.4939Hz
```

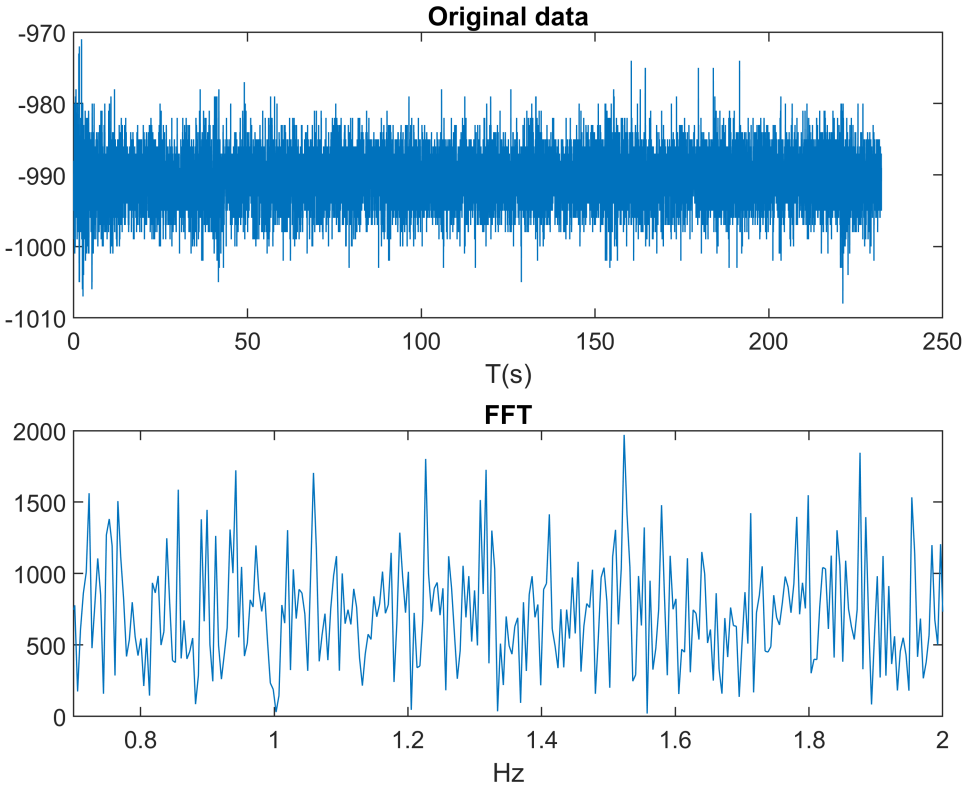
```


f = Fs*(0:(L/2))/L;
```

Z_DATA

```
fft_z = fft(data_set_z - mean(data_set_z));
```

Plots

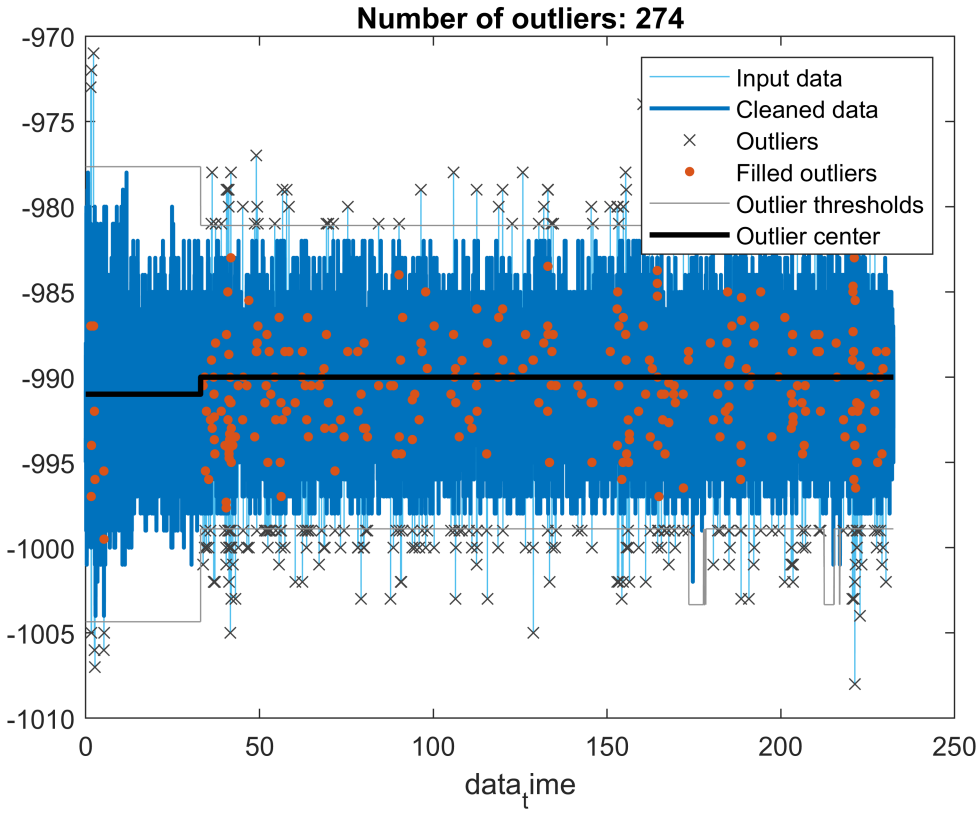
```
figure,
subplot(211),plot(data_time, data_set_z)
title("Original data"),xlabel("T(s)")
subplot(212),plot(f, abs(fft_z(1:numel(f)))*2)
title("FFT"),xlim([0.7, 2]),xlabel("Hz")
```



Remove outliers

```
% Fill outliers
[outliers,outlierIndices,thresholdLow,thresholdHigh,center] = ...
    filloutliers(data_set_z,"linear","movmedian",60,"SamplePoints",data_time);

% Display results
clf
plot(data_time,data_set_z,"Color",[77 190 238]/255,...
    "DisplayName","Input data")
hold on
plot(data_time,outliers,"Color",[0 114 189]/255,"LineWidth",1.5,...
    "DisplayName","Cleaned data")

% Plot outliers
plot(data_time(outlierIndices),data_set_z(outlierIndices),"x",...
    "Color",[64 64 64]/255,"DisplayName","Outliers")
title("Number of outliers: " + nnz(outlierIndices))

% Plot filled outliers
plot(data_time(outlierIndices),outliers(outlierIndices),".","MarkerSize",12,...
    "Color",[217 83 25]/255,"DisplayName","Filled outliers")

% Plot outlier thresholds
plot([data_time(:); missing; data_time(:)],...
    [thresholdHigh(:); missing; thresholdLow(:)],"Color",[145 145 145]/255,...
    "DisplayName","Outlier thresholds")
```

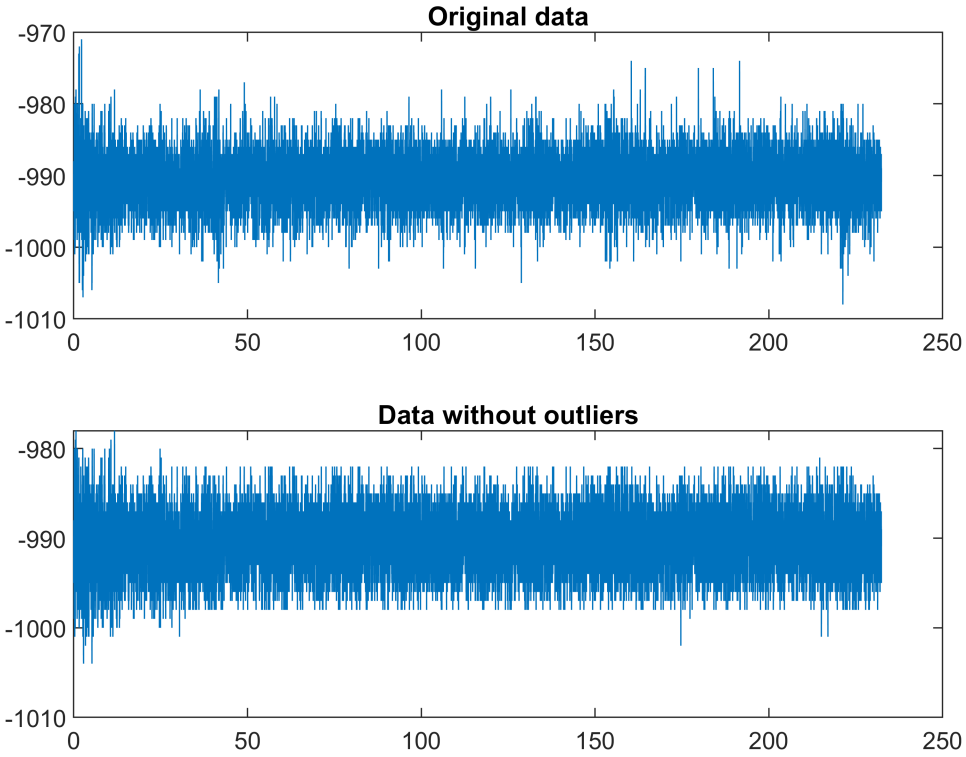
```
% Plot outlier center
plot(data_time,center,"k","LineWidth",2,"DisplayName","Outlier center")

hold off
legend
xlabel("data_time")
```



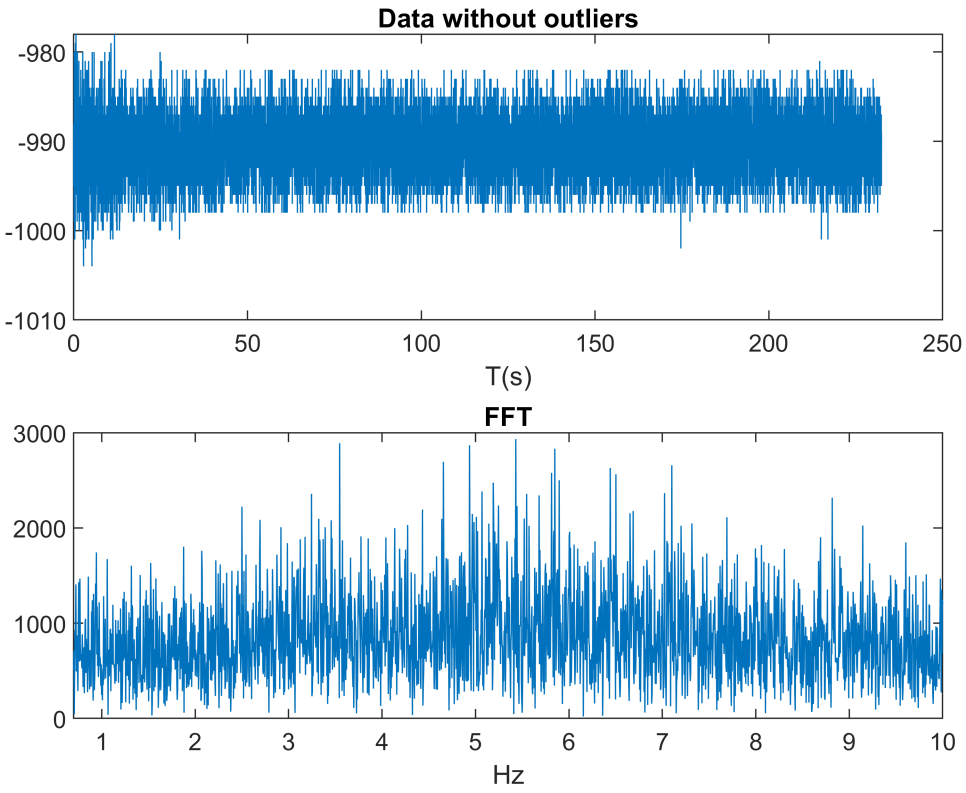

```
clear outlierIndices thresholdLow thresholdHigh center
```

Plots

```
figure,
subplot(211),plot(data_time, data_set_z)
title("Original data")
subplot(212),plot(data_time, outliers)
title("Data without outliers")
```




```
fft_outliers = fft(outliers - mean(outliers));

% Smooth input data
smoothedData = smoothdata(fft_outliers,"movmean",5);

figure,
subplot(211),plot(data_time, outliers)
title("Data without outliers"),xlabel("T(s)")
subplot(212),plot(f, abs(fft_outliers(1:numel(f)))*2)
title("FFT"),xlim([0.7, 10]),xlabel("Hz")
```

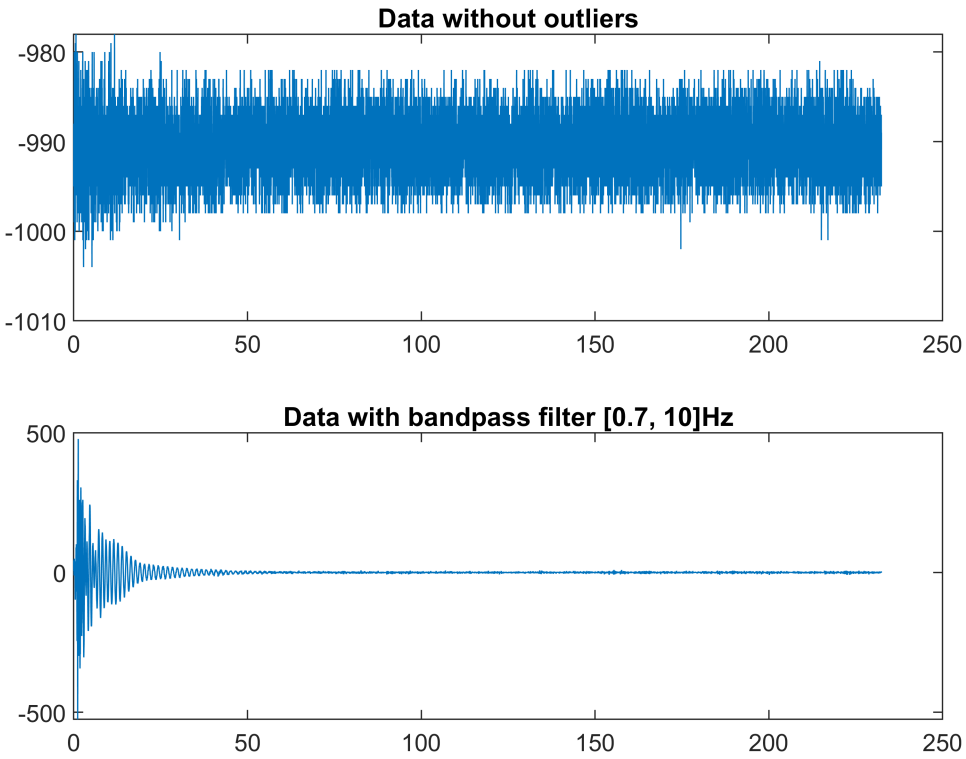


Bandpass filter [0.7 - 10]Hz

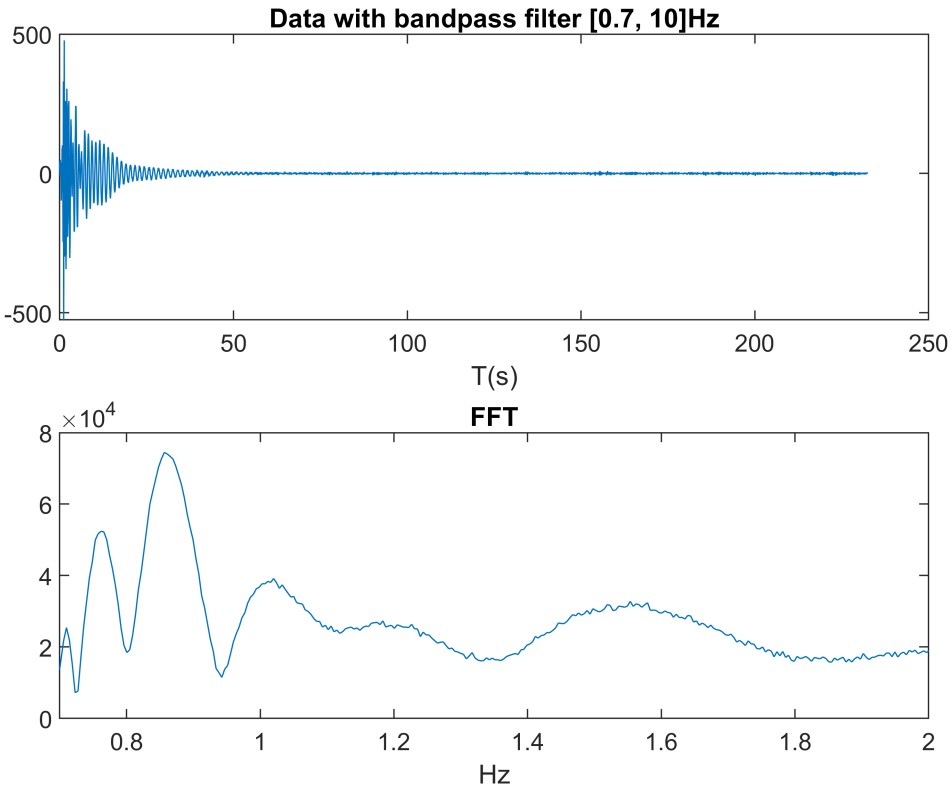
```
% Hd = butter_ecg(Fs);
% filtered = filter(Hd,outliers);
filtered = filter_bpm(outliers);
```

Plots

```
figure,
subplot(211),plot(data_time, outliers)
title("Data without outliers")
subplot(212),plot(data_time, filtered)
title("Data with bandpass filter [0.7, 10]Hz")
```




```
fft_filtered = fft(filtered);

figure,
subplot(211),plot(data_time, filtered)
title("Data with bandpass filter [0.7, 10]Hz"),xlabel("T(s)")
subplot(212),plot(f, abs(fft_filtered(1:numel(f)))*2)
title("FFT"),xlim([0.7, 2]),xlabel("Hz")
```




```
[~, I] = max(abs(fft_filtered(1:numel(f)))*2);
disp("Estimated frequency: " + f(I) + "Hz")
```

```
Estimated frequency: 0.85641Hz
```

```
disp("Estimated BPM: " + f(I)*60)
```

```
Estimated BPM: 51.3848
```

Segmentation and Windowing

Segmentation

```
samples_15s = round(Fs*15);
samples_60s = samples_15s * 4;
[segmented, time_array] = segment_data(filtered,data_time,samples_60s,samples_15s);

f_segment = Fs*(0:(samples_60s/2))/samples_60s;

n = size(segmented,2)
```

```
n = 11
```

Windowing

```
windowed = hamming(samples_60s,"symmetric") .* segmented;
```

BPM

```
fft_windows = fft(windowed);
```

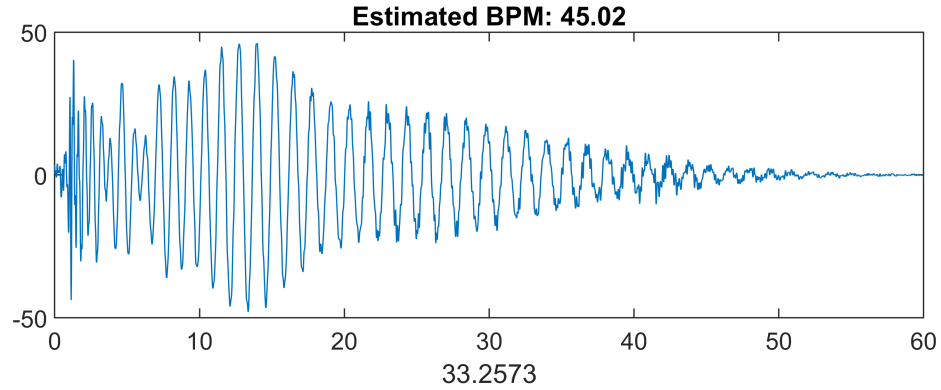
```
index_7 = find(f_segment>.7,1)
```

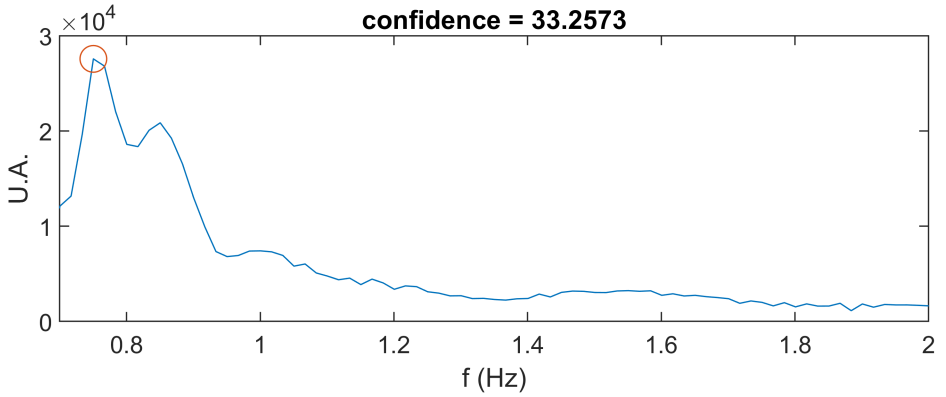
```
index_7 = 43
```

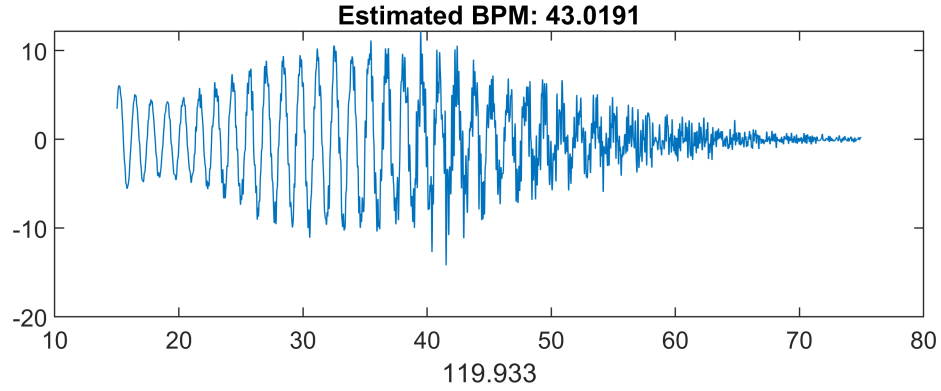
```
index_100 = find(f_segment<2,1,"last")
```

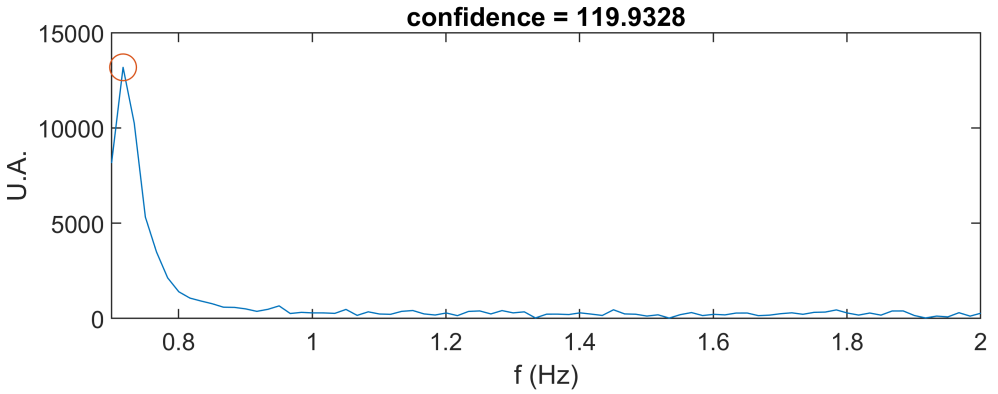
```
index_100 = 120
```

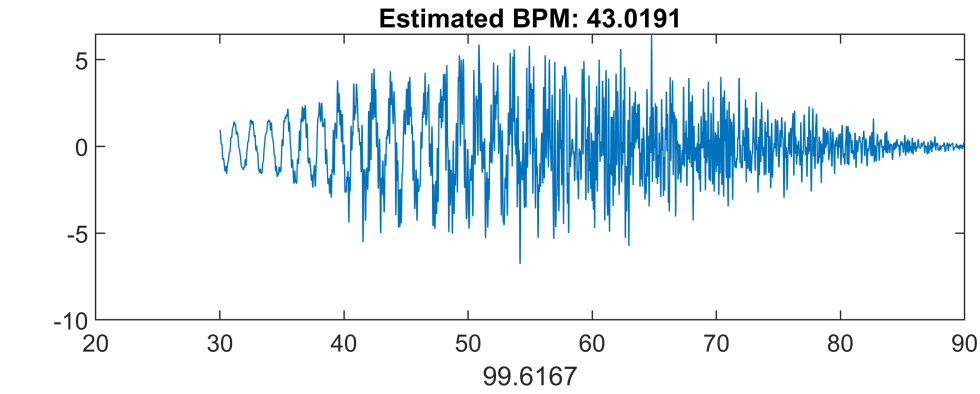
```
bpms = zeros(1,n);
figure
for count = 1:n
    figure
    fft_cut = fft_windows(1:numel(f_segment),count);
    [M, I] = max(abs(fft_cut(index_7:index_100))*2);
    bpms(count) = f_segment(I+index_7-1)*60;

    subplot(211)
    plot(time_array(:,count),windowed(:,count))
    title("Estimated BPM: "+bpms(count))
    conf = confidence(fft_windows(1:numel(f_segment),count),f_segment,0.7,2);
    xlabel(conf)

    subplot(212)

    if conf > 25
        plot(f_segment, abs(fft_cut)*2)
    else
        plot(f_segment, abs(fft_cut)*2, "r")
    end
    xlim([0.7, 2])
    title("confidence = " + conf)
    xlabel("f (Hz)"),ylabel("U.A.")

    hold on
    plot(f_segment(I+index_7-1), M, 'o', 'MarkerSize', 10)
end
```

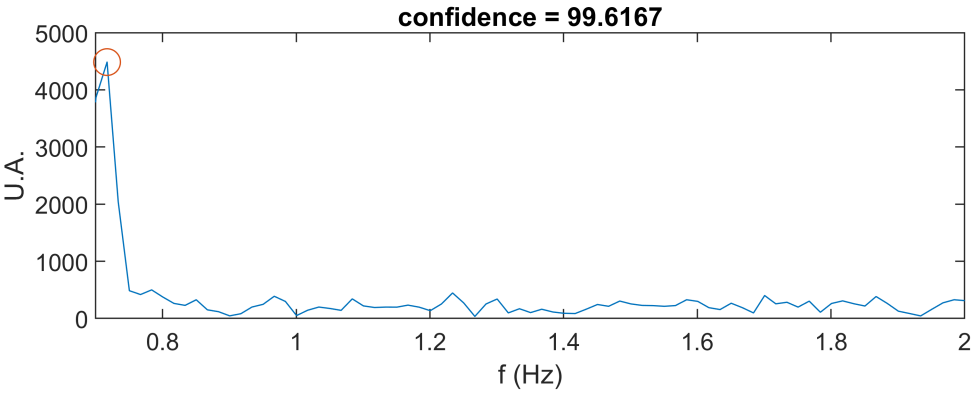

Estimated BPM: 45.02
50
0
-50
0
10
20
30
40
50
60
33.2573

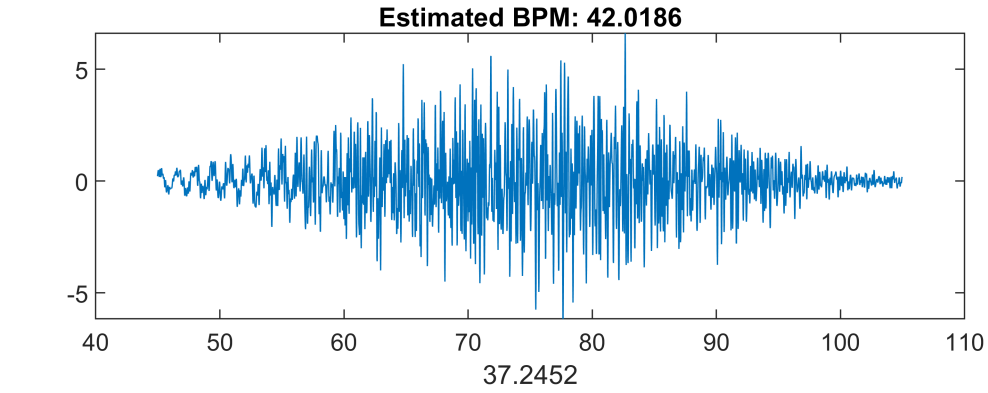

confidence = 33.2573
×10^4
3
2
1
0
U.A.
0.8
1
1.2
1.4
1.6
1.8
2
f (Hz)

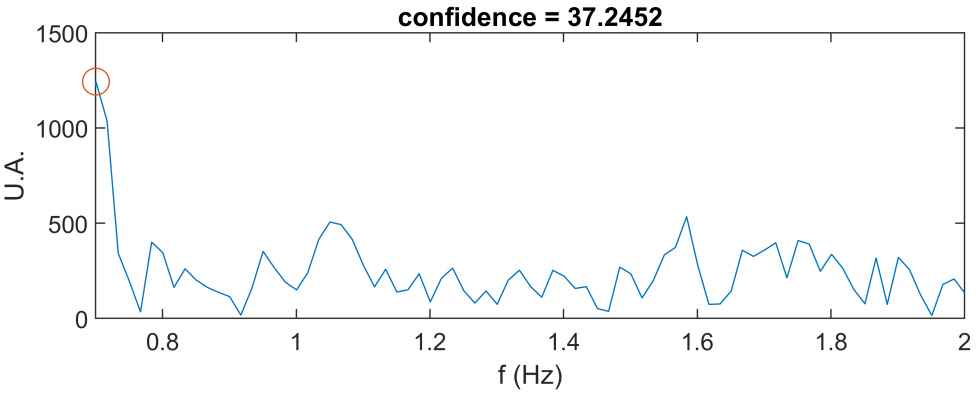

Estimated BPM: 43.0191
10
0
-10
-20
10
20
30
40
50
60
70
80
119.933

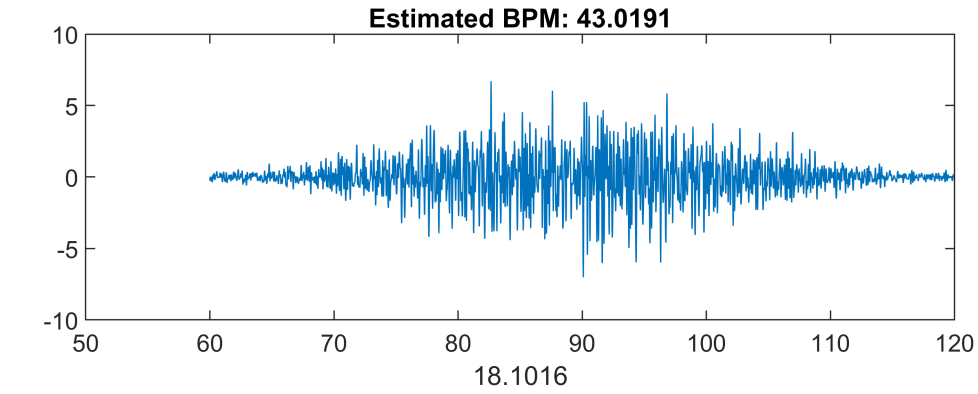

confidence = 119.9328
15000
10000
5000
0
U.A.
0.8
1
1.2
1.4
1.6
1.8
2
f (Hz)

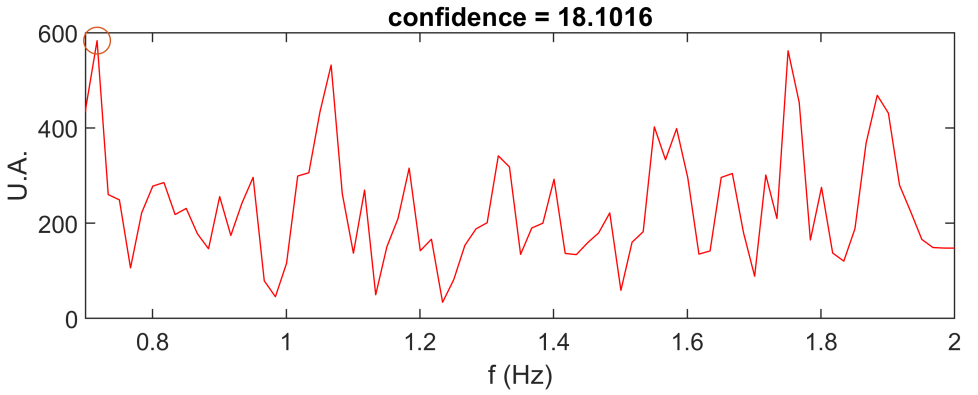

Estimated BPM: 43.0191
5
0
-5
-10
20
30
40
50
60
70
80
90
99.6167

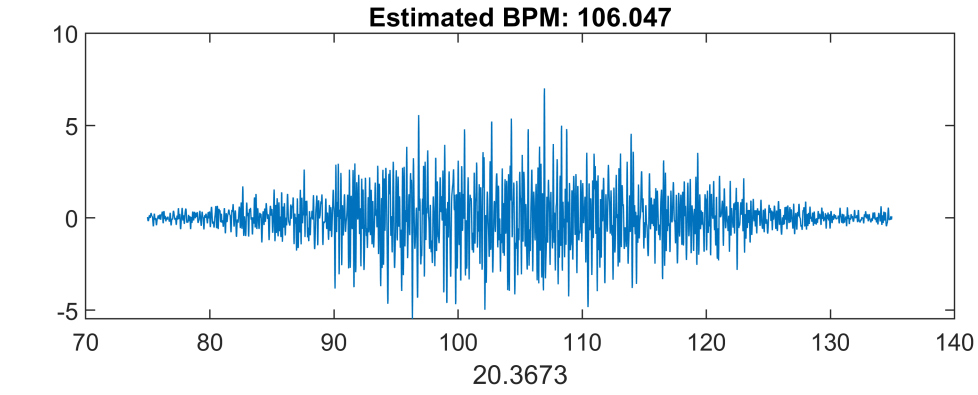

confidence = 99.6167
5000
4000
3000
2000
1000
0
U.A.
0.8
1
1.2
1.4
1.6
1.8
2
f (Hz)

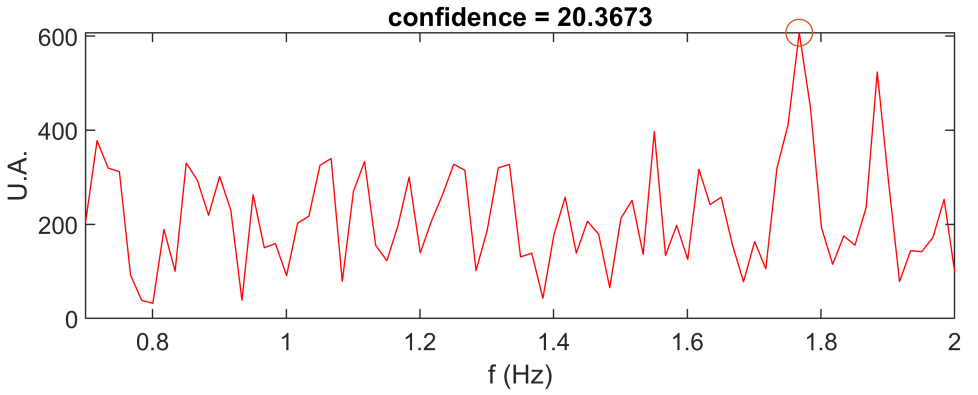

Estimated BPM: 42.0186
5
0
-5
40
50
60
70
80
90
100
110
37.2452

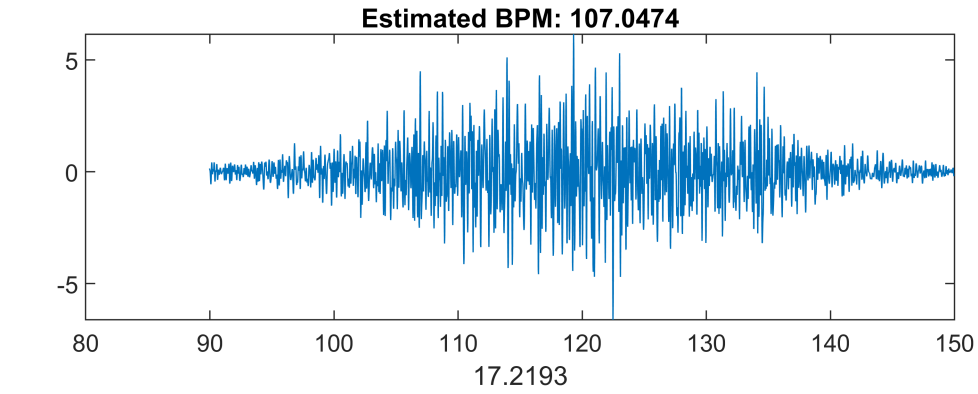

confidence = 37.2452
1500
1000
500
0
U.A.
0.8
1
1.2
1.4
1.6
1.8
2
f (Hz)

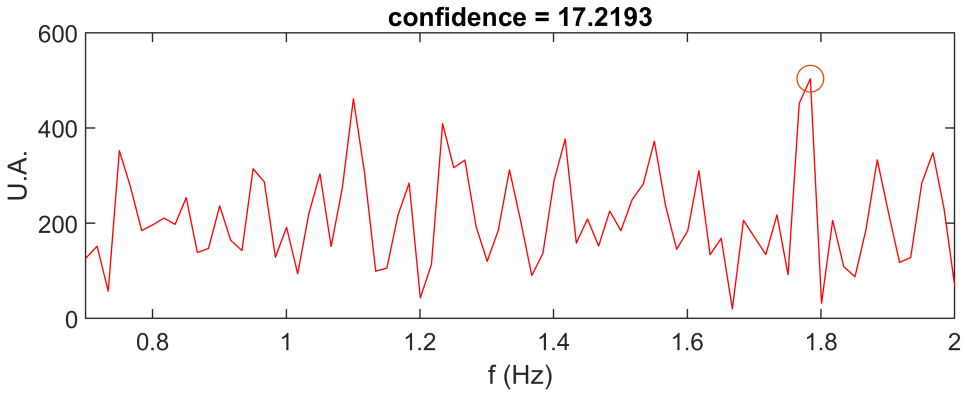

Estimated BPM: 43.0191
18.1016

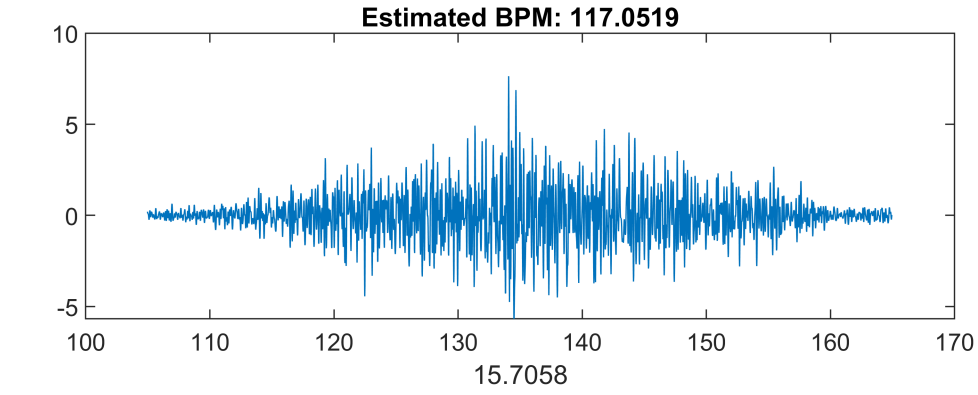

confidence = 18.1016
U.A.
f (Hz)

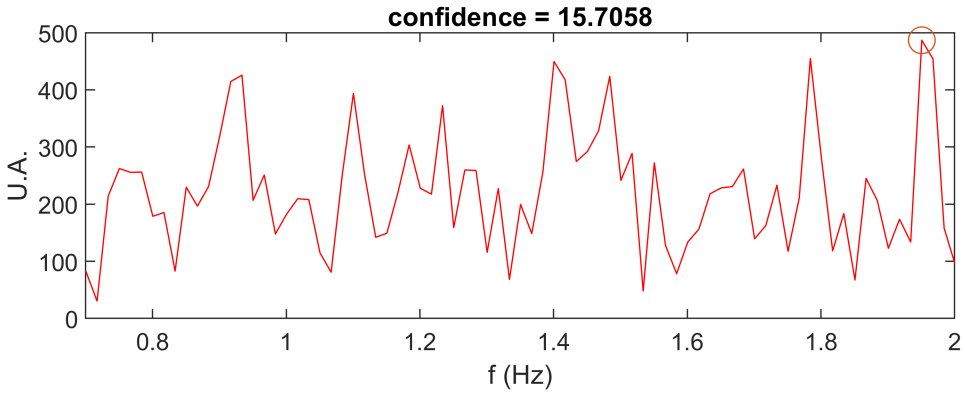

Estimated BPM: 106.047
20.3673

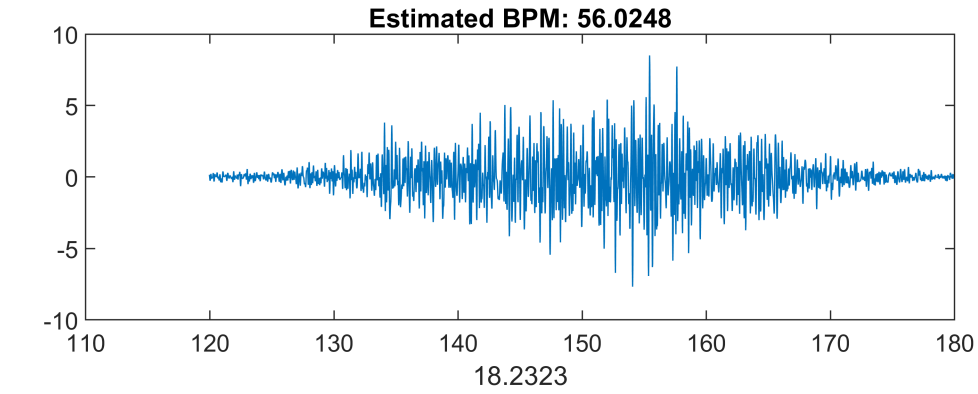

confidence = 20.3673
U.A.
f (Hz)

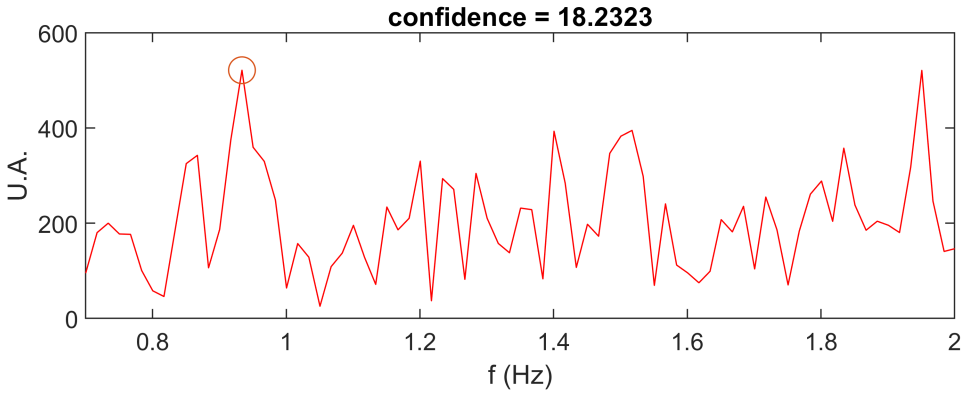

Estimated BPM: 107.0474
17.2193

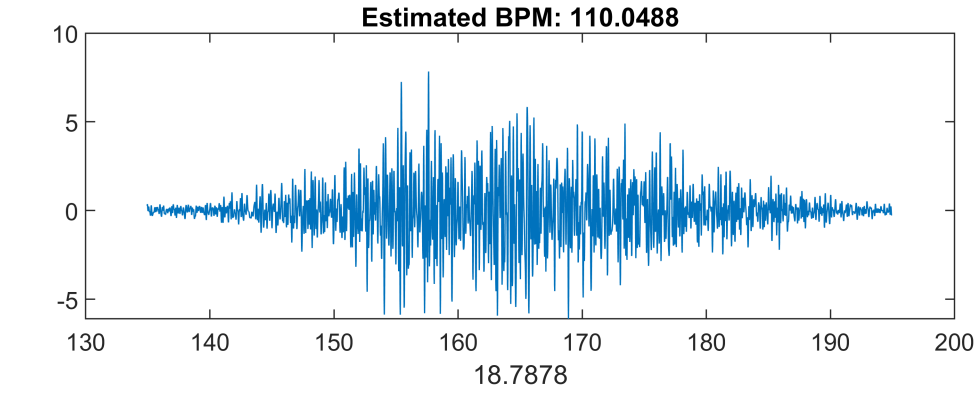

confidence = 17.2193
U.A.
f (Hz)

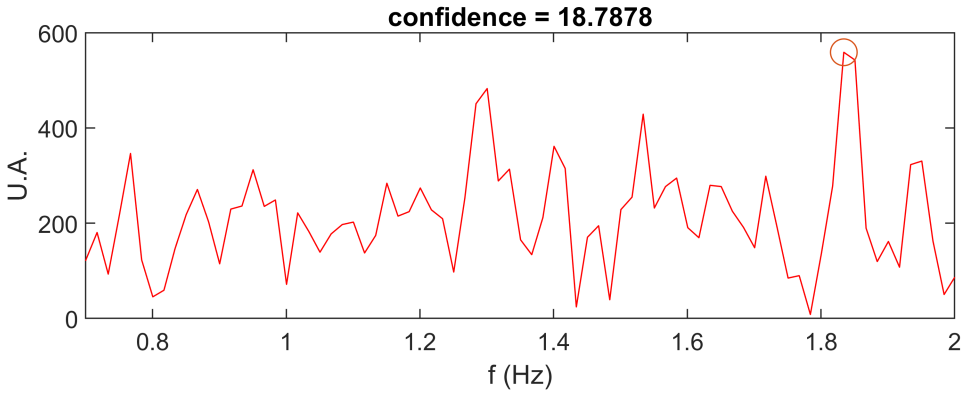

Estimated BPM: 117.0519
15.7058

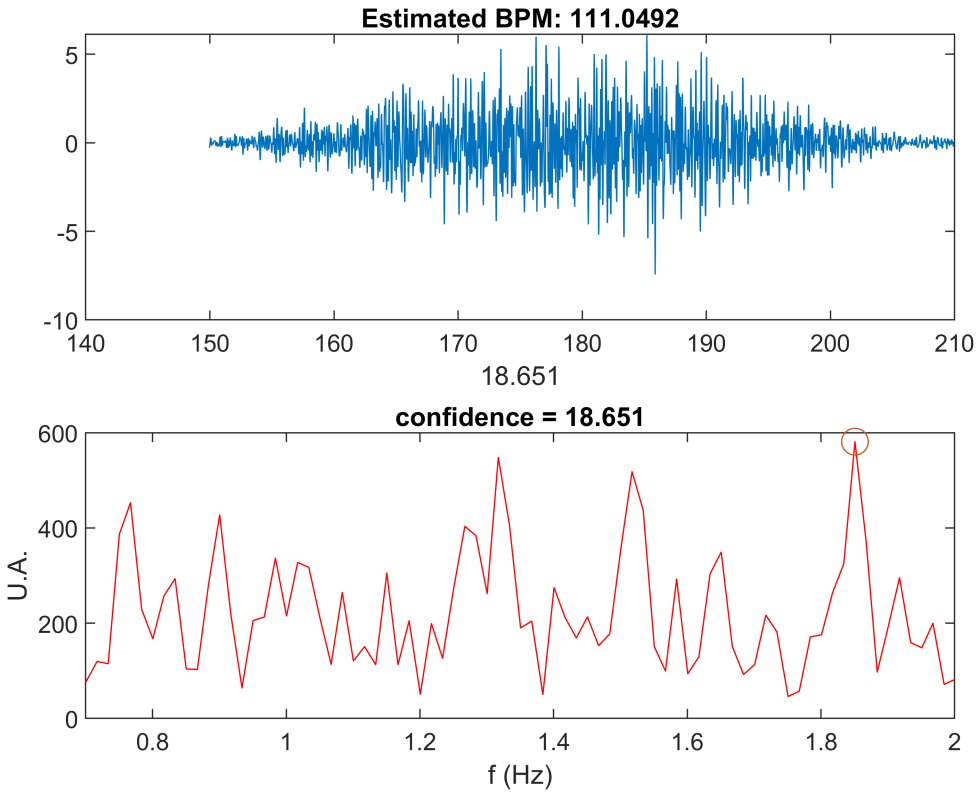

confidence = 15.7058
U.A.
f (Hz)


Estimated BPM: 56.0248
10
5
0
-5
-10
110
120
130
140
150
160
170
180
18.2323


confidence = 18.2323
600
400
200
0
U.A.
0.8
1
1.2
1.4
1.6
1.8
2
f (Hz)


Estimated BPM: 110.0488
10
5
0
-5
130
140
150
160
170
180
190
200
18.7878


confidence = 18.7878
600
400
200
0
U.A.
0.8
1
1.2
1.4
1.6
1.8
2
f (Hz)



Hilbert Transform

```
ht_data = abs(hilbert(windowed)).^2;
```

Fourier Transform

```
fft_data = fft(ht_data);
```

BPM

```
bpms = zeros(1,n);

index_7 = find(f_segment>.7,1)
```

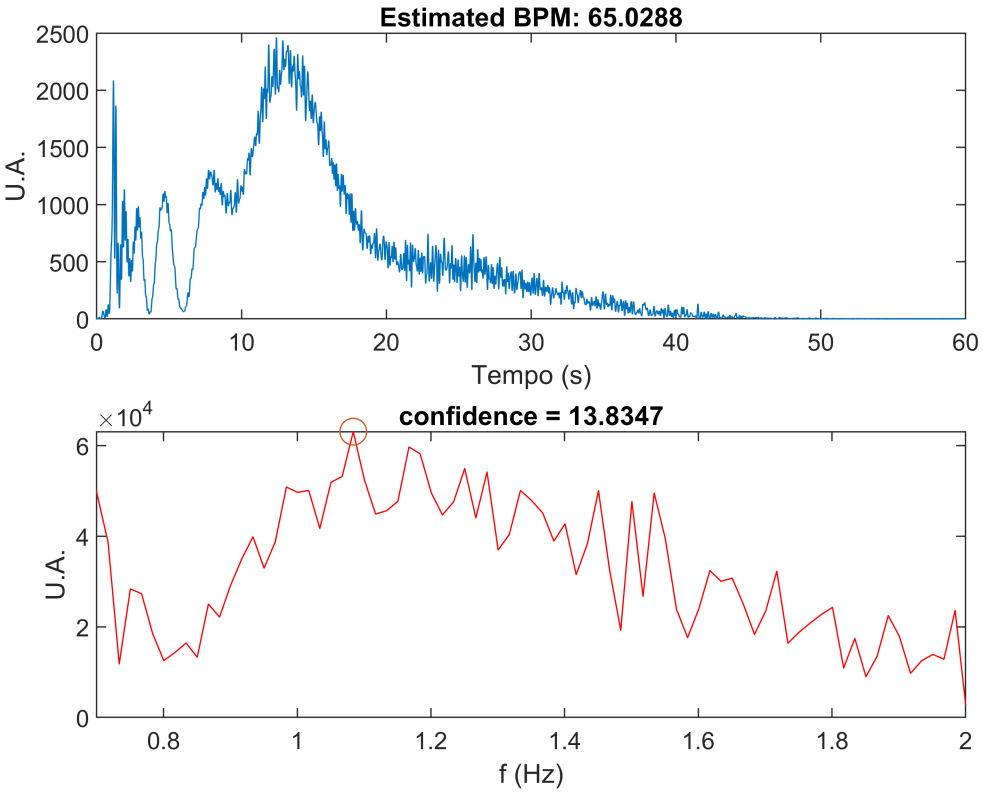
```
index_7 = 43
```

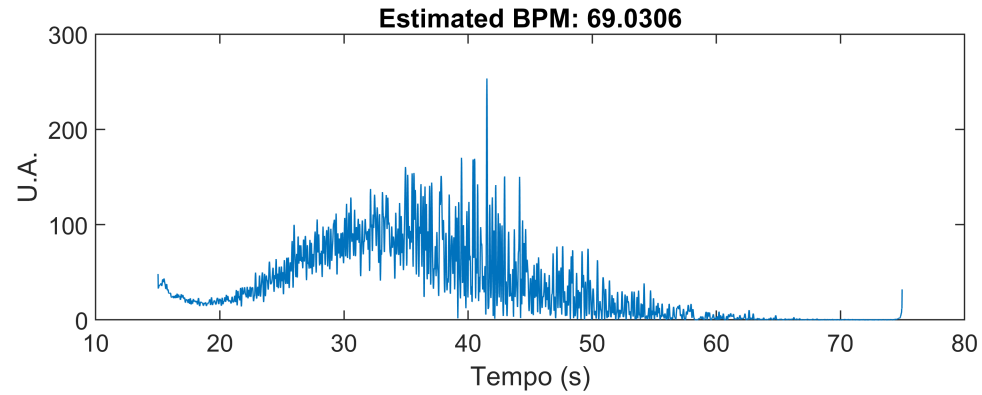
```
index_100 = find(f_segment<2,1,"last")
```

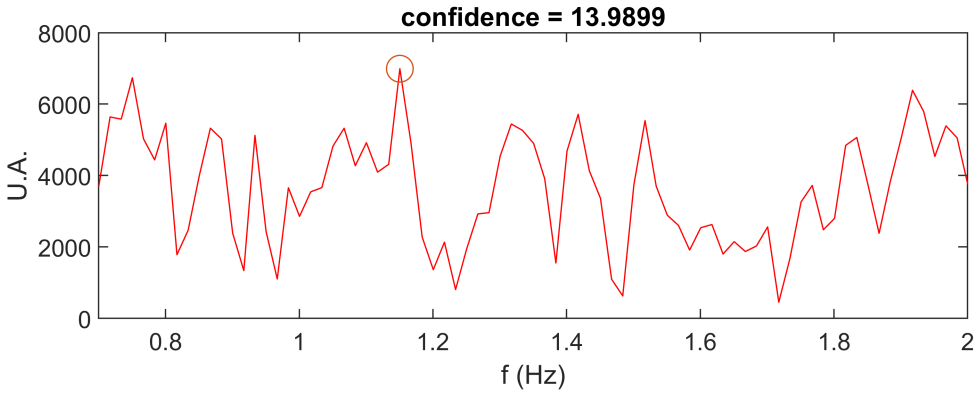
```
index_100 = 120
```

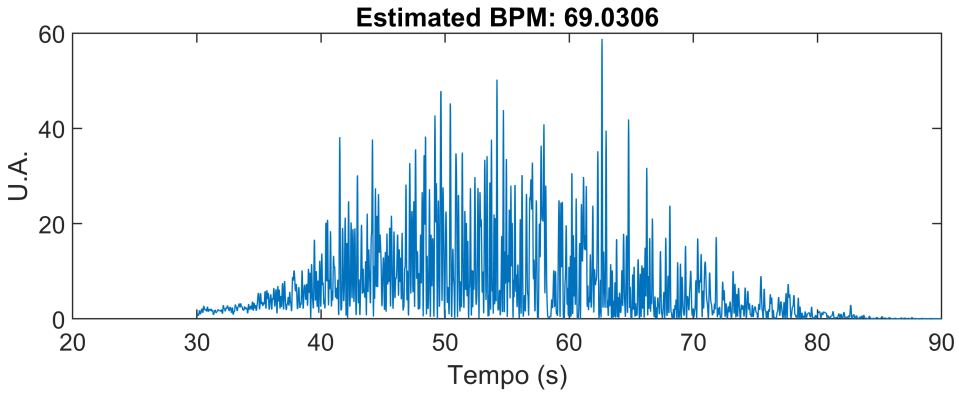
```
figure
for count = 1:n
    figure
    fft_cut = fft_data(1:numel(f_segment),count);
    [M, I] = max(abs(fft_cut(index_7:index_100))*2);
    bpms(count) = f_segment(I+index_7-1)*60;
```

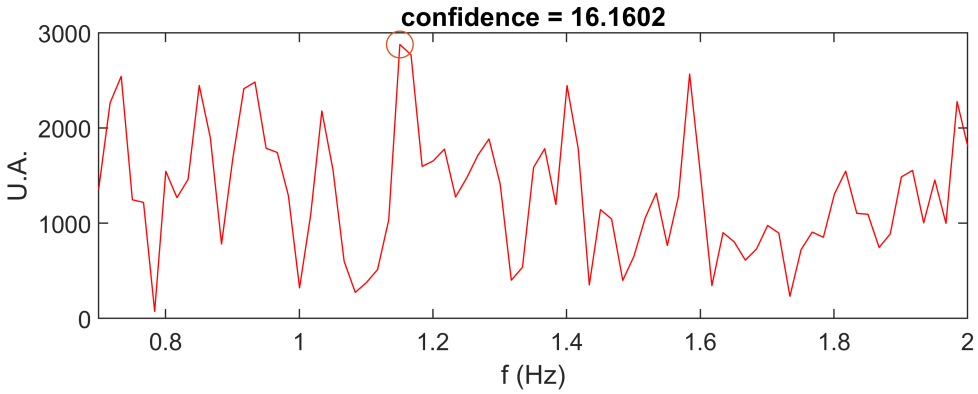
```
    subplot(211)
    plot(time_array(:,count),ht_data(:,count))
    title("Estimated BPM: "+bpms(count))
    xlabel("Tempo (s)"),ylabel("U.A.")

    conf = confidence(fft_cut,f_segment,0.7,2);
    subplot(212)
    if conf > 25
        plot(f_segment, abs(fft_cut)*2)
    else
        plot(f_segment, abs(fft_cut)*2, "r")
    end
    xlim([0.7, 2])
    title("confidence = " + conf)
    xlabel("f (Hz)"),ylabel("U.A.")

    hold on
    plot(f_segment(I+index_7-1), M, 'o', 'MarkerSize', 10)
    disp("------------------------------------------------------------------------")
end
```

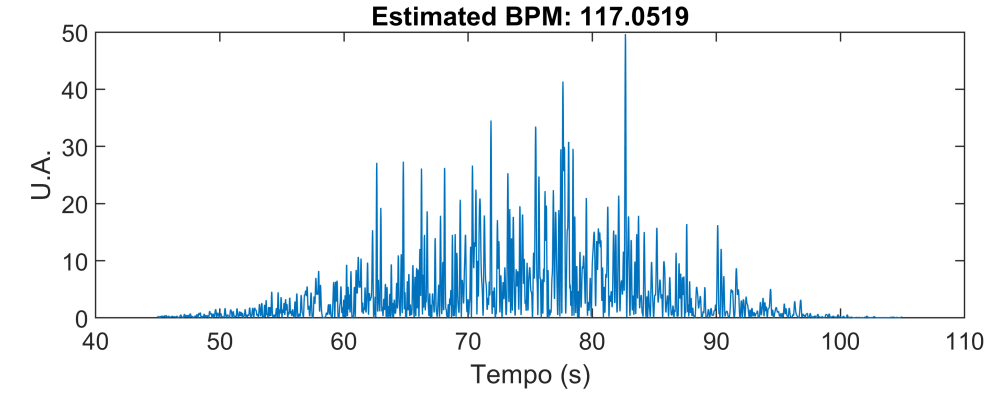


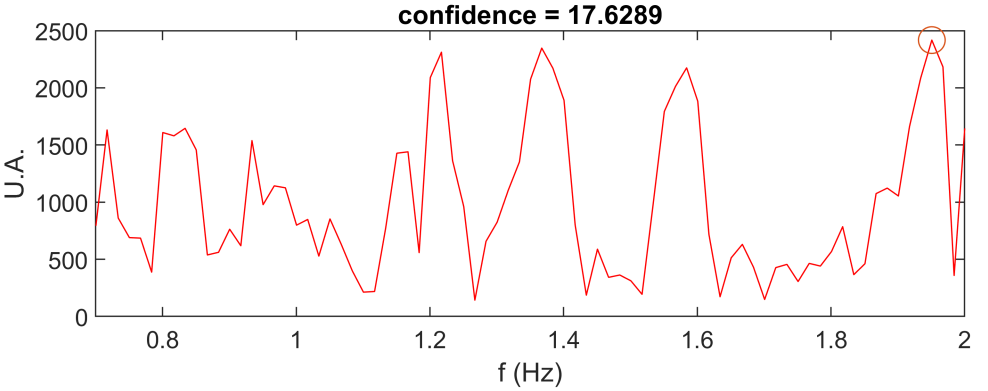

Estimated BPM: 69.0306
U.A.
Tempo (s)

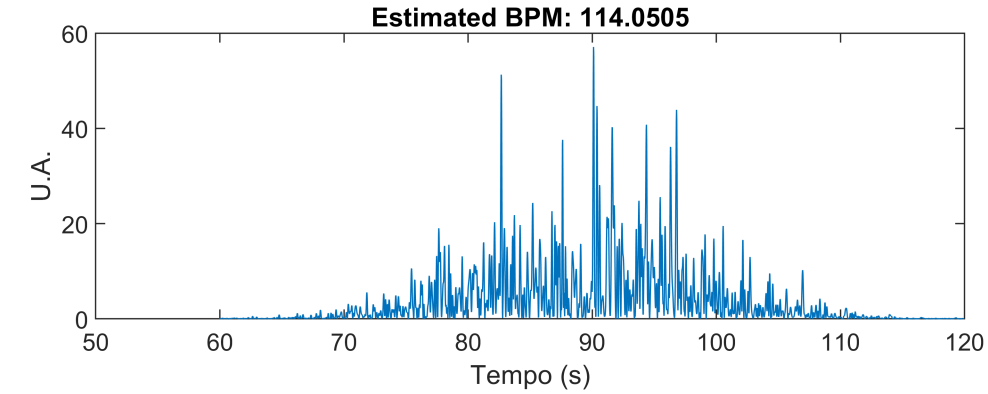

confidence = 13.9899
U.A.
f (Hz)

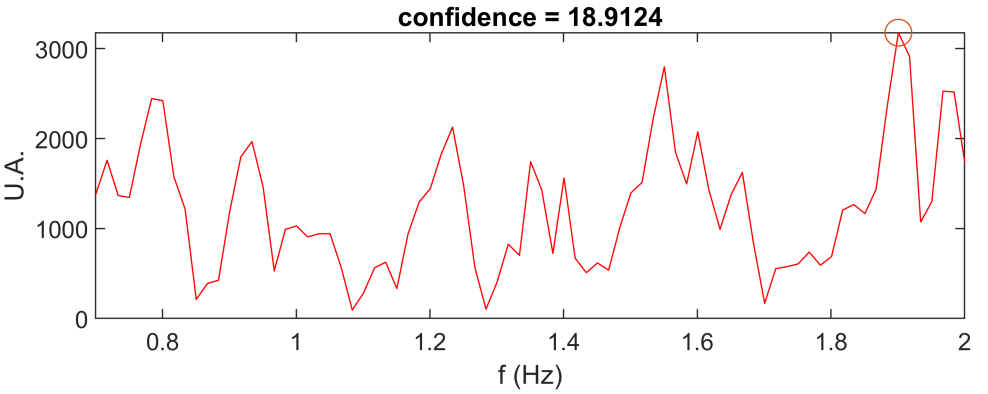

Estimated BPM: 69.0306
U.A.
Tempo (s)

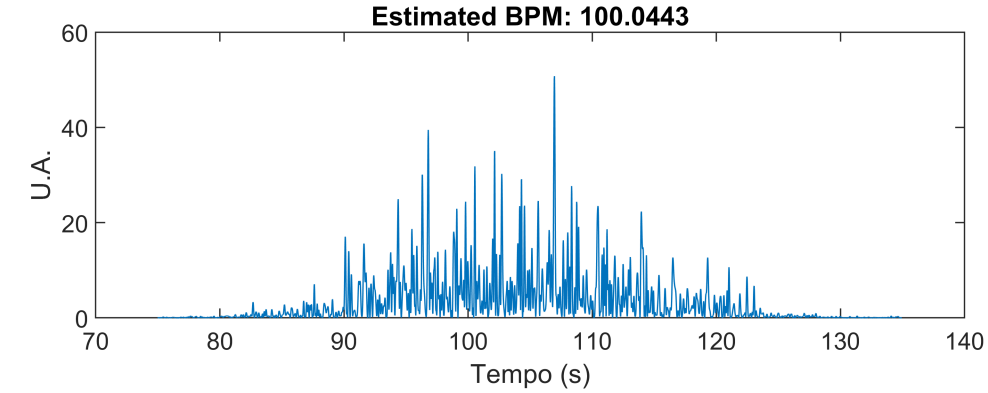

confidence = 16.1602
U.A.
f (Hz)

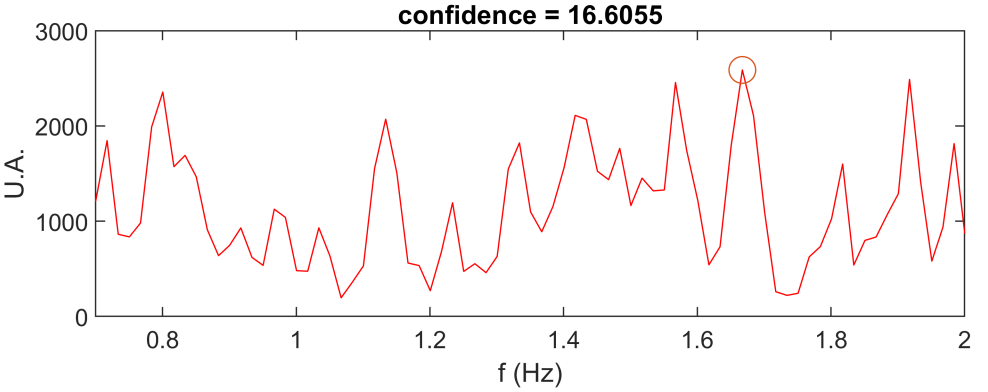

Estimated BPM: 117.0519
U.A.
Tempo (s)

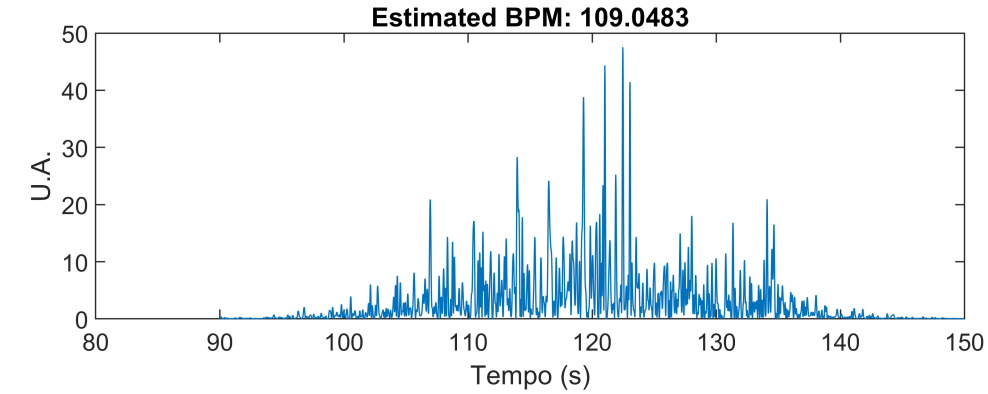

confidence = 17.6289
U.A.
f (Hz)

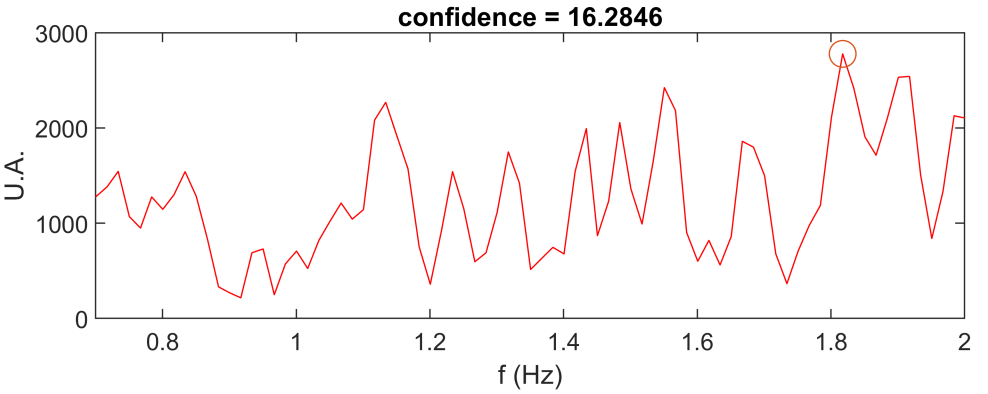

Estimated BPM: 114.0505
U.A.
Tempo (s)

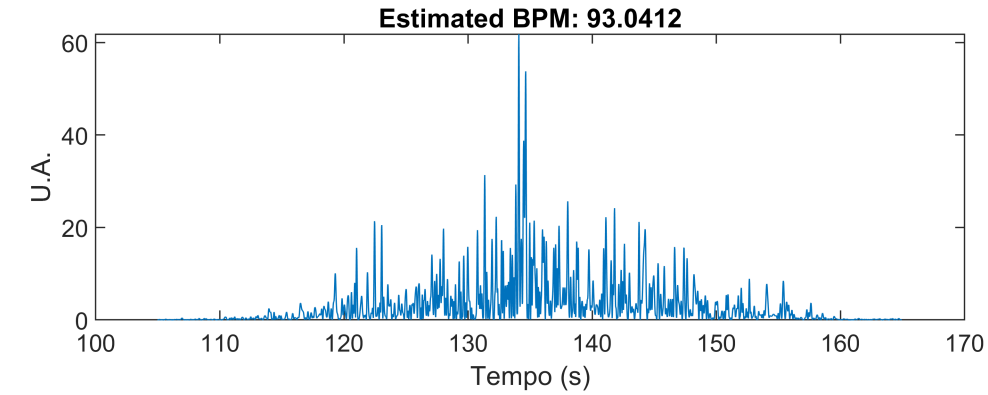

confidence = 18.9124
U.A.
f (Hz)

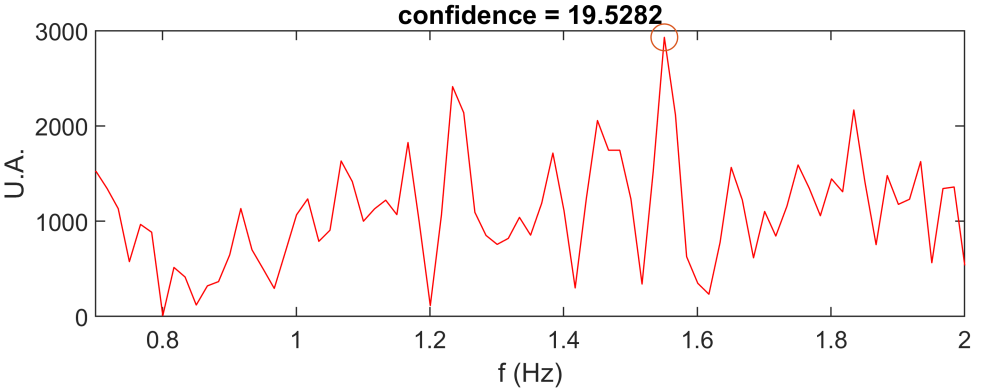

Estimated BPM: 100.0443
U.A.
Tempo (s)

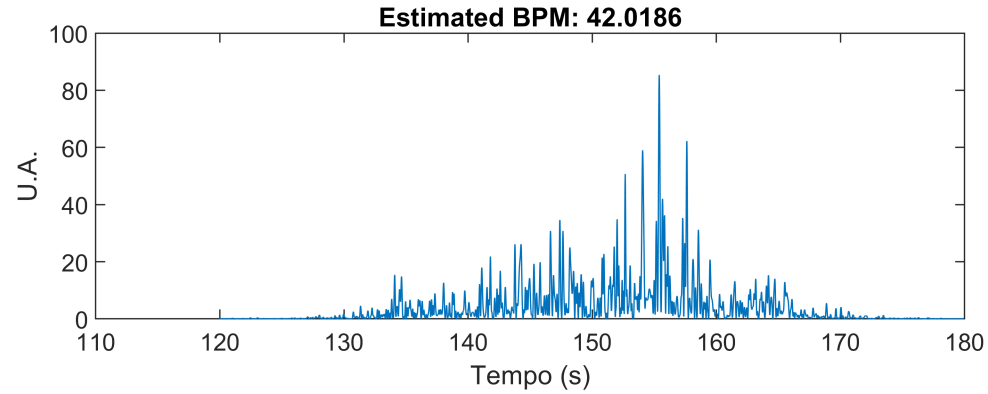

confidence = 16.6055
U.A.
f (Hz)

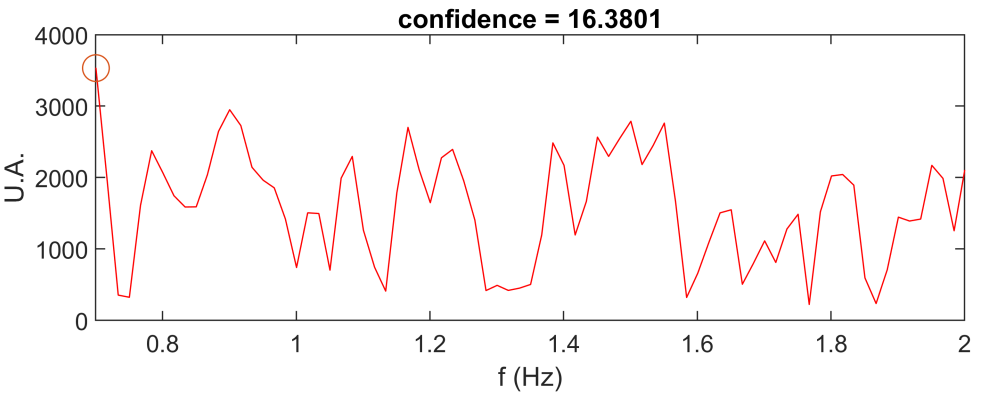

Estimated BPM: 109.0483
U.A.
Tempo (s)

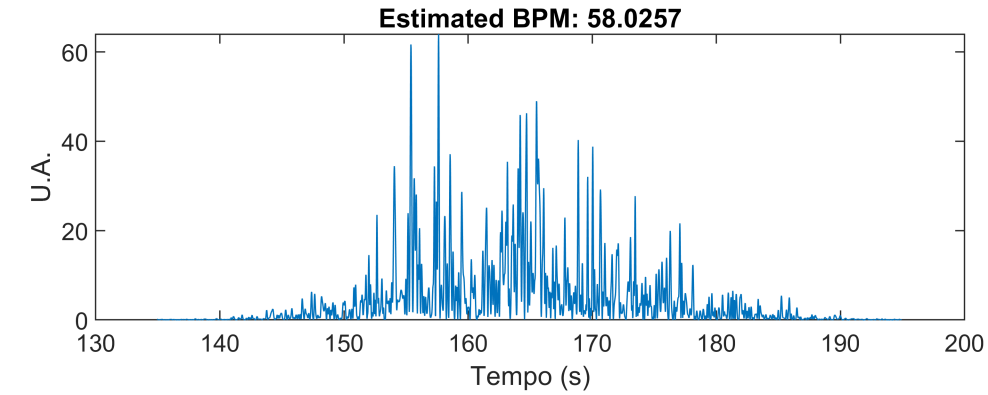

confidence = 16.2846
U.A.
f (Hz)

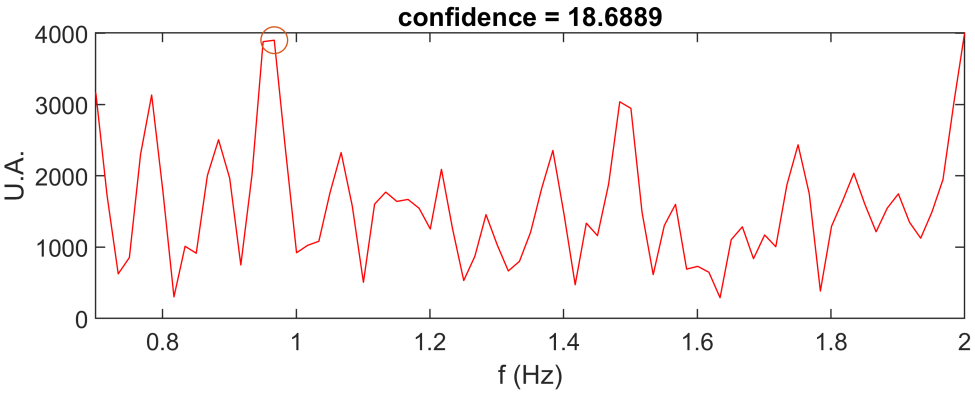

Estimated BPM: 93.0412
U.A.
Tempo (s)

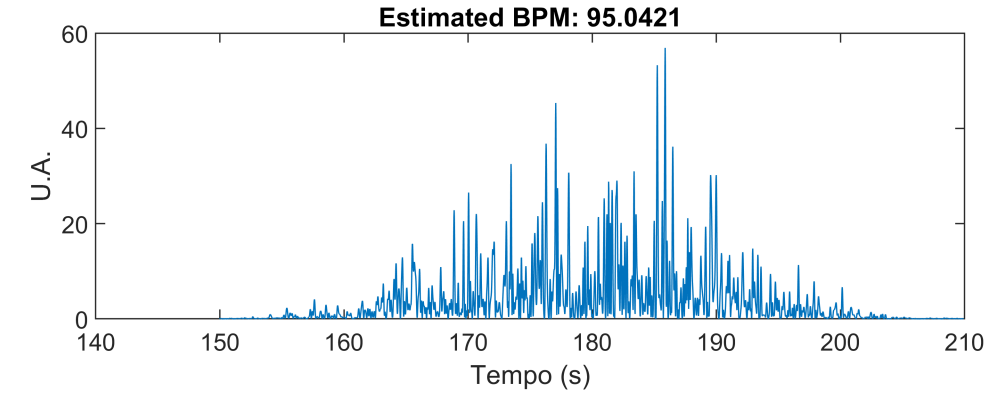

confidence = 19.5282
U.A.
f (Hz)

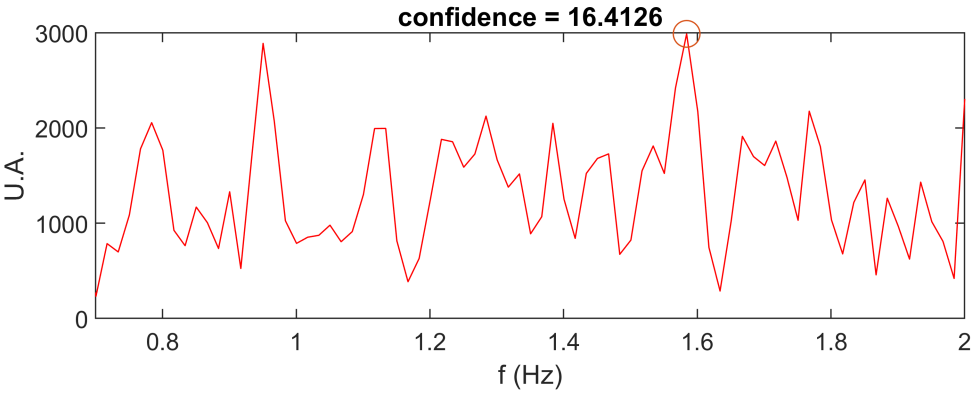

Estimated BPM: 42.0186
U.A.
Tempo (s)


confidence = 16.3801
U.A.
f (Hz)


Estimated BPM: 58.0257
U.A.
Tempo (s)


confidence = 18.6889
U.A.
f (Hz)


Estimated BPM: 95.0421
U.A.
Tempo (s)


confidence = 16.4126
U.A.
f (Hz)
