Brno University of Technology
Faculty of Information Technology

Project Report for ISS

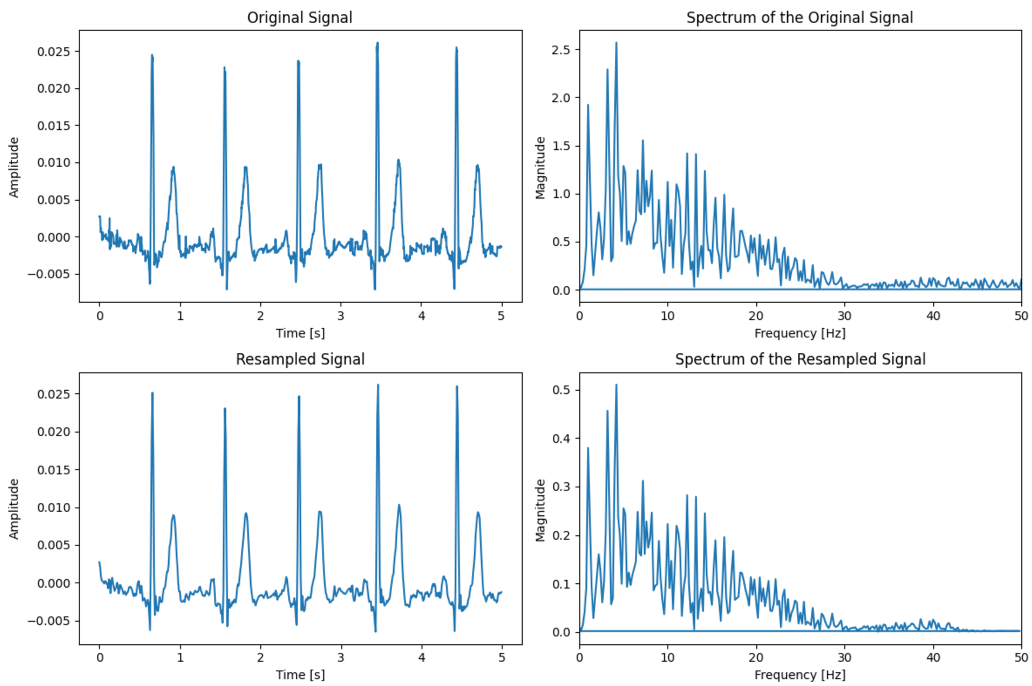
December 12, 2023 Filip Botlo (xbotlo01)

1 Analysis of EKG Signal

1.1 Signal Resampling

In this part of the project, I focused on resampling the EKG signal. I began by designing a low-pass Butterworth filter of the fifth order with a cutoff frequency just below 50 Hz to minimize aliasing effects during resampling. I computed the filter coefficients and applied the filter to the signal using the ‘butter‘ and ‘filtfilt‘ functions from the ‘scipy.signal‘ library.

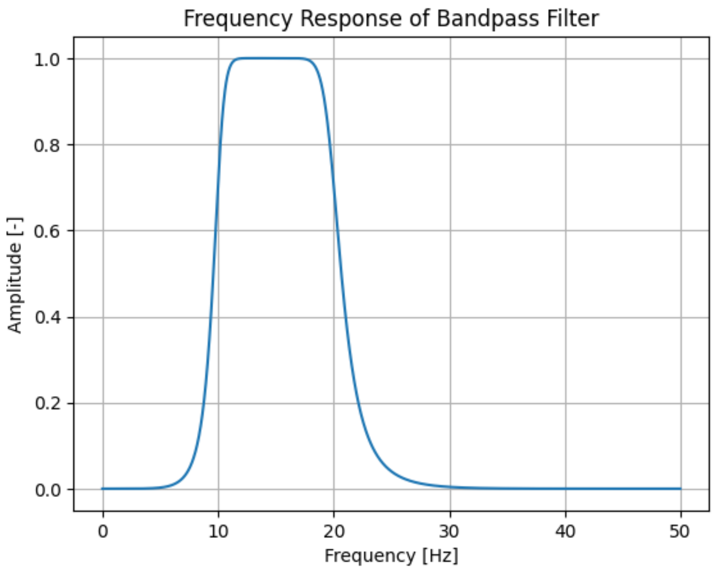
After filtering, I resampled the signal to the desired sampling frequency of 100 Hz using the ‘decimate‘ function. This step reduced the number of samples in the signal, making it easier for further processing and analysis.

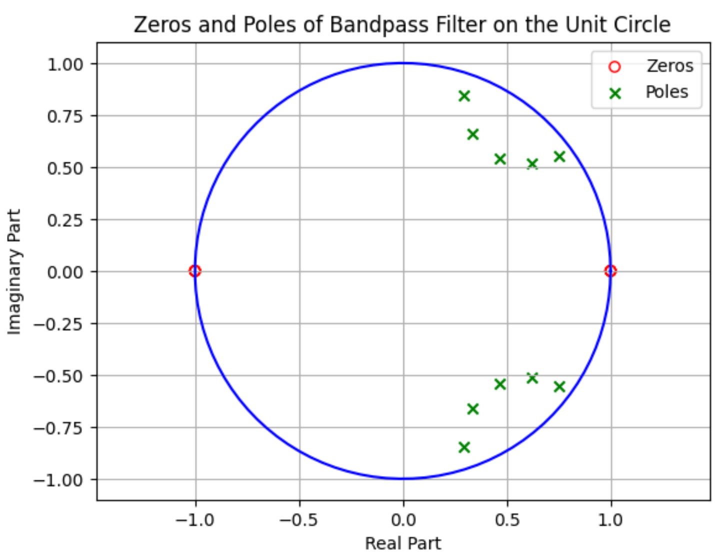


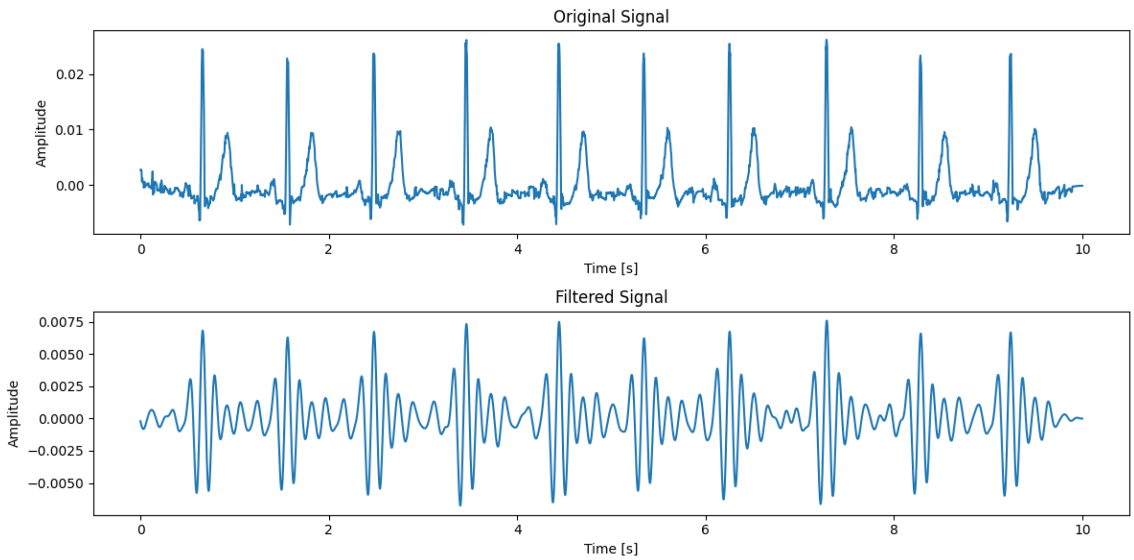
1.2 Signal Filtering

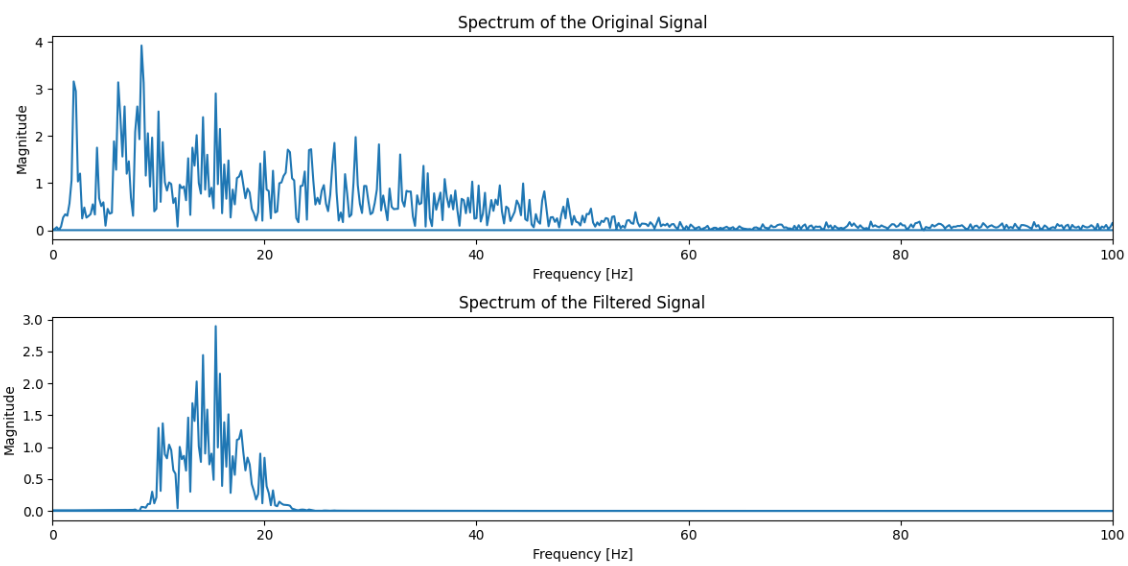
I started by designing a fifth-order Butterworth bandpass filter. The lower and upper frequency bounds of the filter were set to 10 Hz and 20 Hz, focusing on enhancing specific frequency components of the signal.

I used the ‘filtfilt‘ function from the ‘scipy.signal‘ library, which allows filter application without phase distortion. This means that the filter was applied in both directions, ensuring the preservation of the signal’s temporal characteristics.






Original Signal
Amplitude
0.02
0.01
0.00
0
2
4
6
8
10
Time [s]
Filtered Signal
Amplitude
0.0075
0.0050
0.0025
0.0000
−0.0025
−0.0050
0
2
4
6
8
10
Time [s]


Spectrum of the Original Signal
Magnitude
4
3
2
1
0
0
20
40
60
80
100
Frequency [Hz]
Spectrum of the Filtered Signal
Magnitude
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
Frequency [Hz]

2 QRS Complex Detection

2.1 Threshold-based Detection

The process begins by finding the maximum amplitude in the filtered signal. I use the absolute value of the signal to account for possible inversion of QRS complexes.

Subsequently, I set a threshold for detection. The threshold is set at 60% of the maximum signal amplitude. Points in the signal where the value exceeds this threshold are considered potential QRS complex detections.

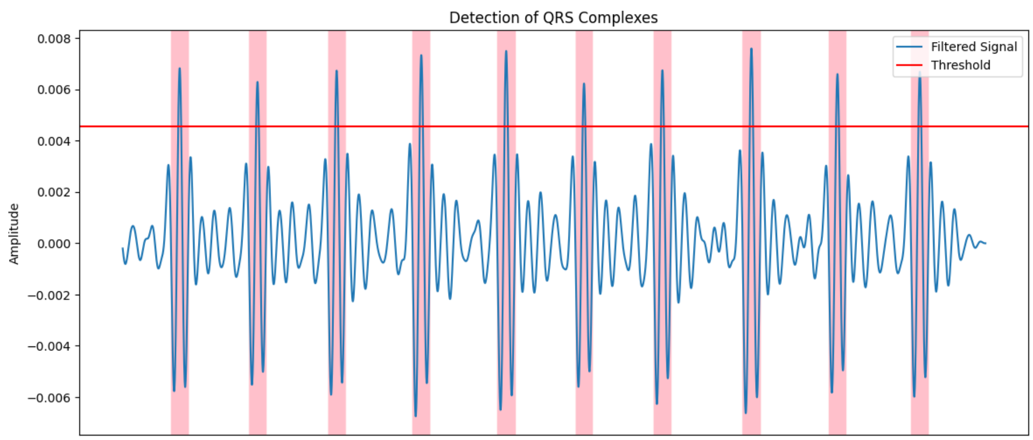
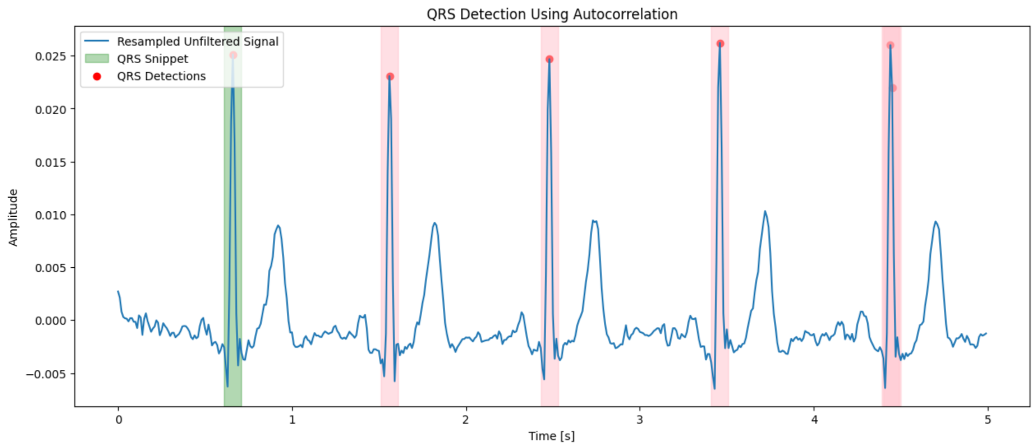


Figure 1: 10s interval

2.2 Autocorrelation-based Detection

I started by identifying the initial prominent peaks in the signal, which I considered indications of QRS complexes. I then performed autocorrelation of a QRS complex sample with the entire signal and identified regions with high correlation.



2.3 Spectrogram-based Detection

First, I set the parameters for the spectrogram, where the hop size was 120 ms, and the window size was 200 ms. I computed the spectrogram using the ‘spectrogram‘ function from the ‘scipy.signal‘ library for the filtered and resampled signal.

I converted the resulting spectrogram to decibels and calculated the sum of spectral energies. I set a threshold based on the mean and standard deviation of the energy sum to identify QRS complexes. I visualized the spectrogram, energy sums, and the original signal, highlighting areas where the energy sum exceeded the threshold.

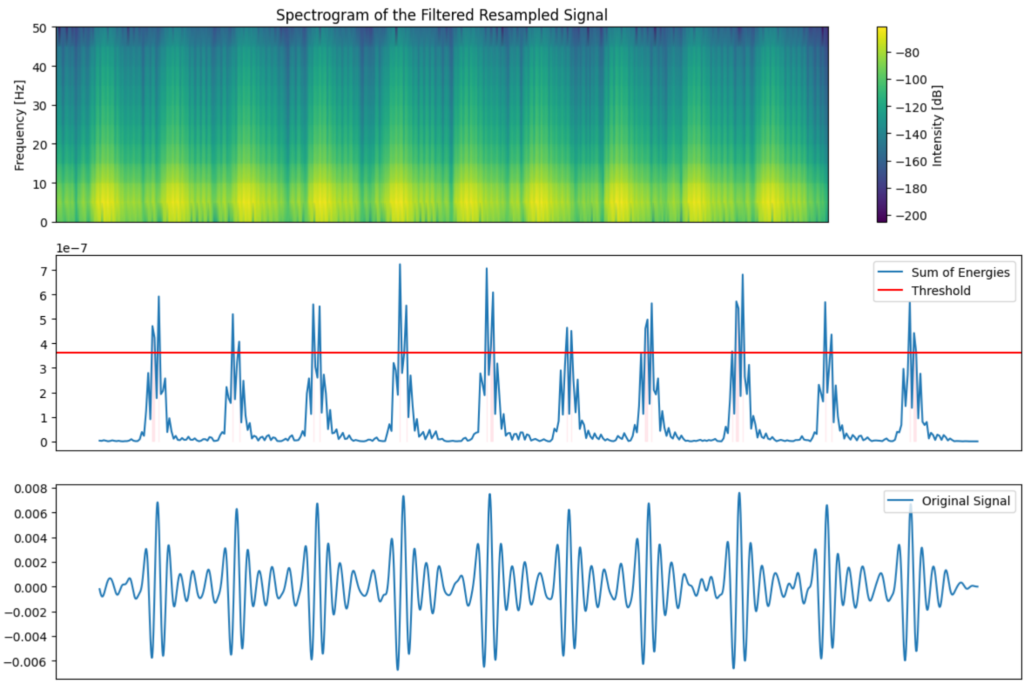


Figure 2: Spectrogram representing a 10-second interval.

2.4 Envelope and Hilbert Transform-based Detection

I first implemented a custom function to perform the Hilbert transform, which multiplied the Fourier transform of the signal by the Heaviside function in the frequency domain. This method allowed me to obtain the analytic signal without using the 'hilbert' function. After obtaining the analytic signal, I calculated its envelope as the absolute value of this signal.

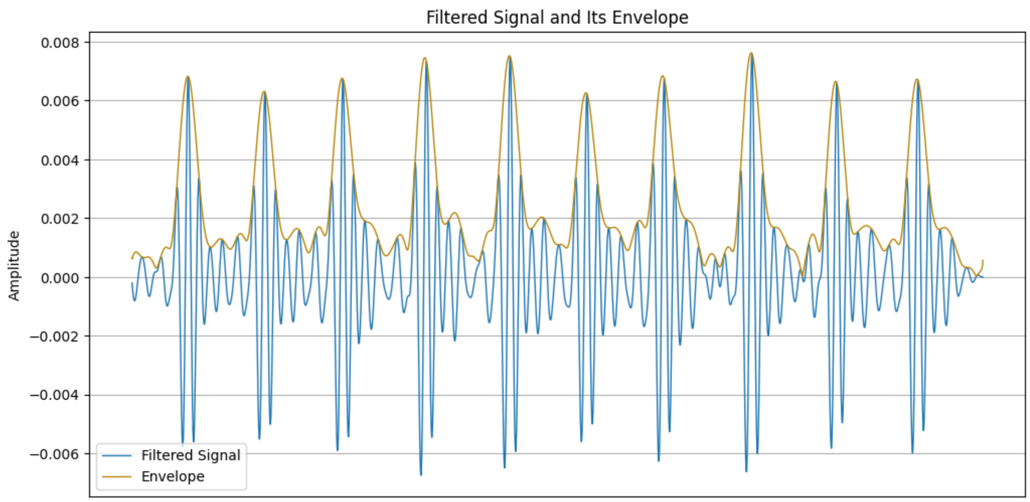


Figure 3: Hilbert Transformation representing a 10-second interval.

3 R-R Interval Detection

I loaded the EKG signal and defined a threshold value for peak detection based on 60% of the maximum signal amplitude. Using the `find_peaks` function from the `scipy.signal` library, I identified peaks that exceeded this threshold.

I assumed that these peaks were QRS complex detections. Based on the indices of these peaks, I calculated the time points in seconds, allowing me to compute R-R intervals. These intervals were then converted to milliseconds.

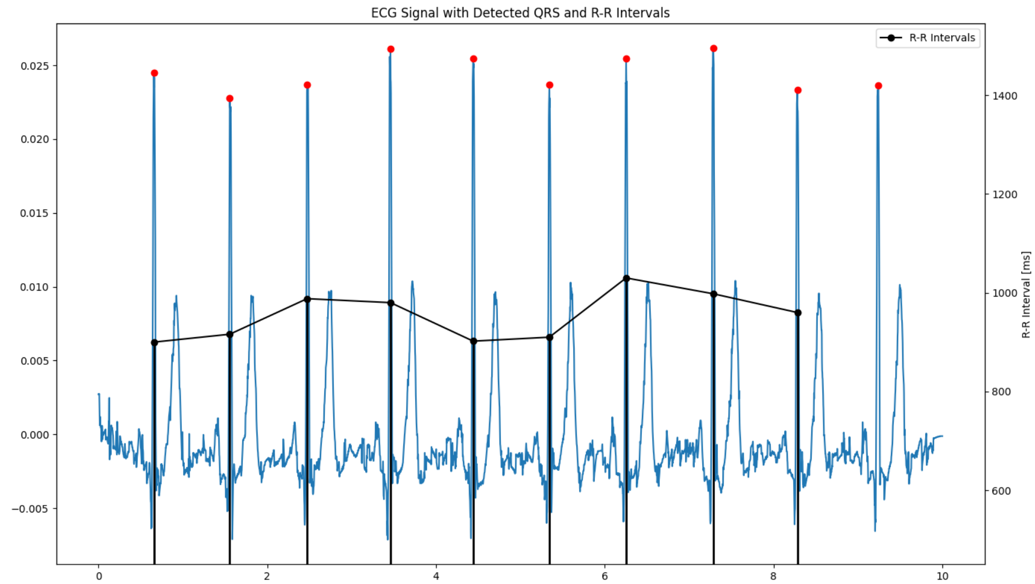


Figure 4: R-R intervals representing a 10-second interval.

4 Conclusion

In this project, I focused on the analysis of EKG signals with an emphasis on QRS complex detection and R-R interval calculation. Using various signal processing techniques such as filtering, resampling, Hilbert transform, and spectrogram computation, I was able to effectively identify important features of the EKG signal.

QRS complex detection was achieved using both threshold-based and autocorrelation-based methods, allowing for precise identification of these crucial points in the signal. Overall, the project demonstrated the effectiveness of combining different signal processing methods for EKG data analysis.