ECG Signal Pre-processing

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Agenda

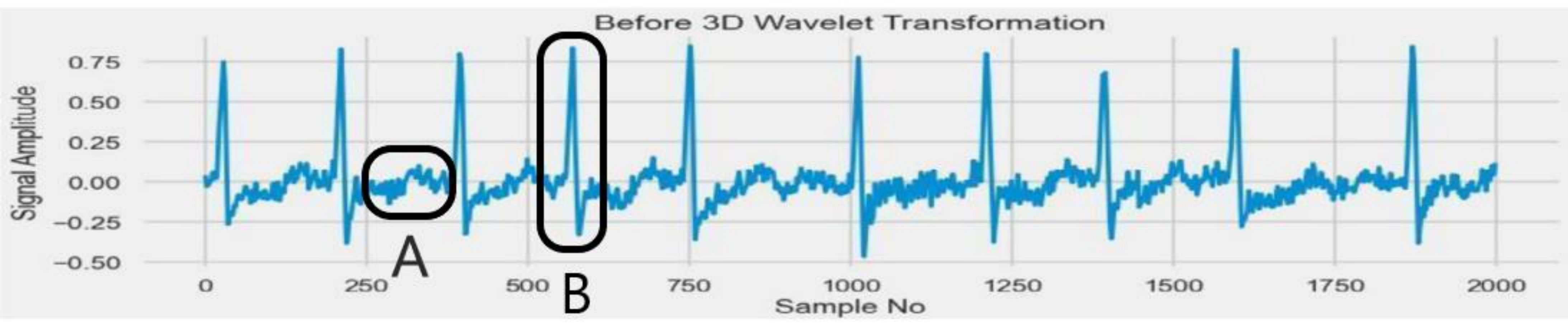
- Introduction and goal
- Why do we need wavelet transform
- Understanding Fourier and Short-time Fourier Transform
- Understanding Wavelet Transform

Introduction and goal

We will explore the advantages of pre-processing the ECG signal using wavelet transform and we will discuss why wavelet transform is better than other options.

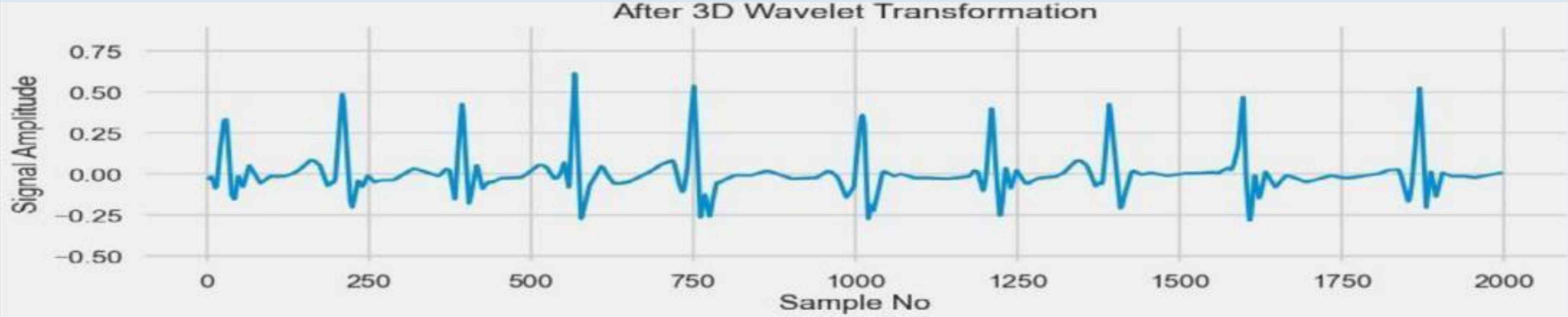
Why do we need wavelet transform

The ECG signal generated has a lot of noise and unwanted parts in it which makes the manipulation much more difficult. So, by using wavelet transform, we can filter out the required parts from the signal. For example, consider the signal,



Why do we need wavelet transform

In the above signal, we see that the frequency of the waves in region A is much greater than the frequency of the waves in region B. So, we can apply wavelet transform to filter out the high frequency part of the waves and then the ECG signal looks like,



Understanding Fourier Transform

The Fourier transform is a mathematical technique that transforms a function of time or space into a function of frequency. It decomposes a function into its constituent frequencies. It is a tool for analyzing functions in the frequency domain rather than the time domain.

The Fourier transform is particularly useful for analyzing periodic phenomena or signals that can be represented as a sum of sinusoidal functions. It segregates the stationary function into various sine and cosine harmonics which persists over the whole time span. So, this means that all the harmonics are present at all times.

Understanding Short-time Fourier Transform

The STFT is a variation of the Fourier transform that allows us to analyze how the frequency content of a signal changes over time. It achieves this by performing Fourier transforms on small, overlapping sections of the signal (called windows) rather than the entire signal at once. By applying the Fourier transform locally over different segments of the signal, the STFT provides a time-varying representation of the signal's frequency content. Narrower windows provide better frequency resolution but poorer time resolution, while wider windows provide better time resolution but poorer frequency resolution. Due to this specific reason, wavelet transform is a much better option than STFT.

Understanding Wavelet Transform

The wavelet transform uses localized wave-like functions called wavelets to transform the function into frequency domain. The transform equation looks like,

$$\left\langle f, \psi_{a,b} \right\rangle = \int_{-\infty}^{\infty} f(t) \psi\left(\frac{t-b}{a}\right) \mathrm{d}t$$

Where, Ψ is the wavelet function. A wavelet is localized wave functions that resemble small ripples and has an effective area of zero. Wavelets follow two fundamental properties: scale, and position.
Scaling characterizes how extended or crowded a wavelet will be, whereas position tells us about the position of the wavelet in the x-axis.

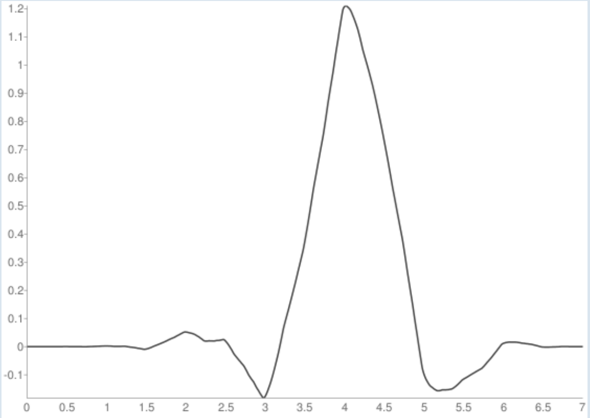
Understanding Wavelet Transform

Scaling is controlled by the parameter 'a' in the equation and the position is controlled by the parameter 'b' in the equation. The parameters are chosen very carefully because a wider wavelet captures lower frequencies, while a narrower wavelet captures higher frequencies. Similarly, translation refers to shifting the wavelet along the time axis. This allows us to analyze the signal at different time points. By using scaled and translated versions of the mother wavelet, the transform calculates how well the wavelet matches the signal at different scales and positions. The results of the wavelet transform are represented by wavelet coefficients which indicates the strength of the match between the scaled and translated wavelet and the signal at each time and scale.

Understanding Wavelet Transform

Higher coefficients signify a better match, implying that the corresponding frequency component is significant at that particular time.

We can use this feature for extracting the QRS complex from the given ECG signal by carefully choosing the mother wavelet. One such wavelet that resembles the QRS complex closely is Symlets 4 or sym4 wavelet which looks like,



Understanding Wavelet Transform

Now, we can apply maximum overlap wavelet transform to get the coefficients up to four approximations. Now, the suitable coefficient can be chosen and we can apply inverse wavelet transform to get the filtered ECG signal back.

In this new filter, we can apply peak detecting algorithms and find the position of the required R peaks.

Reference papers:

https://tinyurl.com/yckfuxve

https://pubmed.ncbi.nlm.nih.gov/30441384/

Thank you

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