SNS Research Project

Fourier Analysis in Cardiovascular Signal Processing

By Razieh Zafar (rz09260) & Nabiha Hasnain (nh09355)

For this Research Project, we have decided to move forward with the topic of analysing Fourier Series in Electrocardiograms (ECGs) and Cardiovascular Signal Processing. In the following paragraphs, we will deduce the topic's WHAT, WHY and HOW.

WHAT:

Fourier Analysis is a mathematical technique used to analyze and process signals by transforming them from the time domain to the frequency domain. In cardiovascular signal processing, it especially plays a crucial role in analyzing ECG signals, which record the electrical activity of the heart. This transformation allows us to see and identify the different frequency components within the ECG which helps in noise reduction, feature extraction and accurate disease diagnosis. By applying Fourier Analysis, various signal-processing techniques such as filtering, spectral analysis and data compression are implemented to enhance the ECG signal quality and extract critical information about heart function.

WHY:

Now onto why use Fourier Series to analyze ECGs; ECG signals are often contaminated by noise from various sources such as the muscle activity, powerline interference, and baseline wander. To elaborate:

1. **Noise Reduction**: It removes unwanted frequency components, making ECG signals clearer for analysis.
2. **Feature Extraction**: Identifies subtle variations in heart rate and beat patterns, which are highly necessary for detecting arrhythmias and other cardiac abnormalities, and as ECG signals are quasi-periodic, Fourier series are ideal for representing periodic signals.
3. **Data Compression**: Large ECG datasets need efficient storage and transmission, and the Fourier-based techniques help greatly by reducing redundant information for easier storage while preserving vital diagnostic details.
4. **Detection of Cardiac Disorders**: Helps spot abnormalities like T-wave alternans and late potentials, which can indicate serious heart conditions.

Hence, Fourier Analysis are a fundamental tool in cardiovascular signal processing, because it simplifies complex signals, highlights essential features and improves the accuracy of diagnosing heart conditions. Without it, ECG interpretation would be much harder and more prone to errors.

HOW:

Since ECG signals are periodic in nature, they can be decomposed into a sum of sinusoidal functions using the Fourier Series. For example, electrical interference from power lines appears at 50/60 Hz frequency components in the ECG. By converting the ECG from the time domain into the frequency domain, the Fourier Transform identifies this interference as a distinct peak. A filter can then be applied to remove just that frequency, leaving the rest of the ECG signal intact. We can also check the difference between irregular heartbeats since patients that are suffering from heart diseases like atrial fibrillation or ventricular tachycardia produce irregular patterns that are not so easily detectable in the time domain. Therefore, by analyzing changes in the spectral components over time, Fourier-based techniques can detect sudden shifts that indicate an abnormal rhythm. Lastly, in high resolution ECG, Fourier Transform can also detect low amplitude signals in background noises that might indicate post heart attack risks.

This is our first step in exploring the Fourier Series and its role in ECG signal processing. As our research progresses, we aim to further investigate the '**WHAT, WHY, and HOW**' of Fourier Series by examining its practical applications in this field.

Reference Paper:

[1] L. Rnmo and P. Laguna, "ELECTROCARDIOGRAM (ECG) SIGNAL PROCESSING," 2006. Available: https://diec.unizar.es/~laguna/personal/publicaciones/libroWiley.pdf