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A Brief Study of Transform in Biomedical Signals.

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Abstract
Biomedical signals like electrocardiogram (ECG), photoplethysmographic (PPG) and blood pressure were very low frequency signals and need to be processed for further diagnosis and clinical monitoring. Transforms like Fourier transform (FT) and Wavelet transform (WT) were extensively used in literature for processing and analysis. In my research work, Fourier and wavelet transforms were utilized to reduce motion artifacts from PPG signals so as to produce correct blood oxygen saturation (SpO2) values. In an important contribution we utilized FT for generation of reference signal for adaptive filter based motion artifact reduction eliminating additional sensor for acquisition of reference signal. Similarly we utilized the transforms for other biomedical signals.[15]
Understanding and analyzing images is challenging. Digital image processing has several uses in the medical field. The most common ones are a CT or MRI scan and a magnetic resonance imaging (MRI) study.
Keywords: *Fourier transform, biomedical signals, electrocardiogram signal, wavelet transform, Fourier Transform Spectroscopy, Magnetic resonance imaging (MRI)*

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I. Introduction

Fourier transforms is one of the oldest and most well known techniques in signal processing. This transform method represents signals as a summation of complex exponentials. Fourier analysis, also termed spectral analysis or Harmonic analysis, decomposes a time-dependent periodic phenomenon into a series of sinusoidal functions, each defined by unique amplitude and phase values. Fourier transform convert complex curve into sum of a series of cosine waves (terms) and an additive term [1]. Each wave is defined by unique amplitude and a phase angle, where the amplitude value is half the height of a wave, and the phase angle (or simply, phase) defines the offset between the origin and the peak of the wave over the range 0 to 2π. Each term designates the number of complete cycles completed by a wave over the defined interval. Successive harmonic terms are added to produce a complex curve and each component curve, or term, accounts for a percentage of the total variance in the original complex curve [1]. Fourier analysis has been used in digital image processing for analysis of a single image as a two-dimensional wave form, and more recently more recently has been used for magnetic resonance imaging, angiographic assessment, automated lung segmentation & image quality assessment and Mobile stethoscope. In this paper we will review the recent application of Fourier transform in medical engineering

II. Applications of Transforms in Biomedical Signals

M. Guerquin-Kern et.al [2] has used Fourier transform for analytical simulation tools that are suited to parallel magnetic resonance imaging and allow one to build realistic phantoms. This paper introduces analytical simulation tools that are suited to parallel magnetic resonance imaging and allow one to build realistic phantoms. The proposed phantoms are composed of ellipses and regions with piecewise-polynomial boundaries, including spline contours, Bézier contours, and polygons. In addition, they take the channel sensitivity into account, for which we investigate two possible models. Analytical formulations provide well defined data in both the spatial and k-space domains. Their main research is the closed-form determination of the Fourier transforms.

Tobias Benz et.al [3] has used Fourier-based approach to the angiographic assessment of flow diverter efficacy in the treatment of cerebral aneurysms. In this article they propose a metric for the angiographic assessment of flow diverter deployments in the treatment of cerebral aneurysms. By analyzing the frequency spectra of signals derived from digital subtraction angiography (DSA) series, the metric aims to quantify the prevalence of frequency components that correspond to the patient specific heart rate. For estimating the power spectral density (PSD) of a time-contrast curves (TCC), the periodogram estimator was used, which is a PSD estimator based on the discrete Fourier transform (DFT).

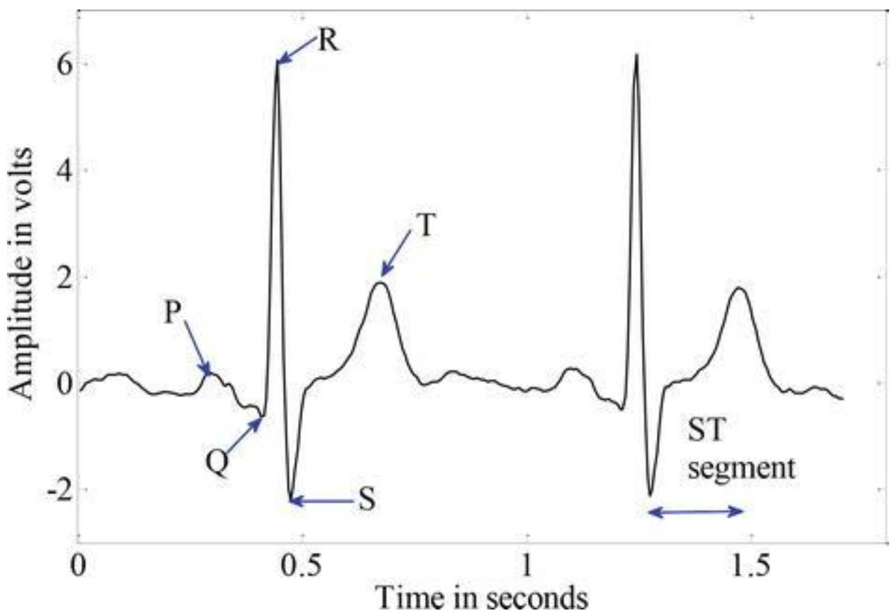
The Fourier transform is essential to all contemporary imaging, but MRIs require it most. The complex periodic signal composed of numerous constituent frequencies is received by the detector (the detector array in CT, the piezoelectric disc in ultrasound, and the receiver coils in MRI). Rapid identification of some yeast and dermatophytes isolated from superficial fungal diseases can be achieved by the use of Fourier transform infrared spectroscopy. Many domains, including contemporary acoustics, voice communication, sonar, earthquakes, nuclear research, and even biomedical engineering, rely heavily on Fourier transform. In today's world, Fourier analysis is an essential tool for systems and signal analysis. In order to clearly detect the frequency and amplitude components that are concealed within a complex signal, the Fourier transform is an essential tool. The frequency and phase encoded MR signals that make up k-space are resolved by the Fourier transform during the creation of an MR image. We observe the MR image of the 2D inverse Fourier transform of k-space. Comprehending the Fourier transform is crucial for comprehending various magnetic resonance artifacts and the diverse data gathering techniques utilized in modern practice.

Because of its nonperturbative and extremely sensitive characteristics, Fourier transform infrared spectroscopy is a fundamental and dependable method with a wide range of possible beneficial applications in the fields of biology and medicine. The wavelength of the light absorbed by the probe at specific vibration frequencies is examined using the FTIR spectroscopic approach. This approach produces a unique spectrum for biological material exposed to radiation; it is referred to as a molecular fingerprint. For food safety and quality in a processing, retail, or production setting, quickly and easily identifying microorganisms is essential. Traditional approaches such as serological testing, biochemical testing, and conventional plating involve multiple steps and may need a considerable amount of time to produce confirmed results.

The integration of Fourier transform spectroscopy techniques with nanotechnology, biology, and medicine presents novel prospects for atom and molecular detection and manipulation using nanodevices, potentially yielding a wide range of cellular biological and medicinal uses.

III. Biomedical Signals

The Electrocardiogram (ECG) is an electrical manifestation of contractile activity of the heart, is a representation of instantaneous electrical activity of the heart during its contraction and relaxation over a period of time. A standard 12 leads ECG is recorded with the help of surface electrodes placed on the limbs and chest. In general, ECG is a widely accepted diagnosis tool in clinical validations of heart related diseases. Figure 2 shows a typical ECG signal, marked with all the characteristic waves and durations such as P wave, QRS complex wave, T wave and ST segment [7]. Electrocardiograms (ECG) are extensively used for the diagnosis of cardiac arrhythmias. A transform is a mathematical tool that moves from the time domain to the frequency domain. The transformation changes the representation of the signal by projecting the signal onto a set of essential functions but does not change the information content of the signal. Various types of feature extraction methods have been available for decades, including FFT, DFT, Short-Time Fourier transform (STFT) and wavelet-based features of, features based on crossed wavelets. The Fast Fourier Transform removes low frequencies from the ECG signal.



IV. Comparative study of various transform.

The comparative study of various transform techniques for biomedical signal gives an idea about the advancement in biomedical field. The transform techniques like FFT, WT, Laplace Transform, Hilbert Transform and Hadamard Transform were used in biomedical signal analysis. The WT has become one of the emerging tool for time and feature analysis of ECG and EEG data. The WT has ability to extract the related component of the signal using variety of wavelet-based techniques as far better than the traditional Fourier transform methods. The laplace transform basically used to detect the ischemia event in ECG signal. The advantage of Hilbert Transform is that it changes the phase value without changing the spectral component of the amplitude. The Hadamard Transform is well known for low memory requirement and less computational complexity. The EEG is a non-stationary and nonlinear signal, which doesn't fallow any fix pattern. The continuous wavelet transform (CWT) has ability to perform efficient analysis of non-stationary signal over a wide range of applications. The CWT allows arbitrary high resolution of signal in time frequency domain. Normally CWT based algorithms used for identification of epileptic seizure in EEG data.

The above table mainly shows the utility of transform for the analysis of ECG signal using various transform techniques but few transform techniques among them are also suitable for EEG signal analysis like continuous WT, Hilbert transform, Hadamard transform. The average accuracy in feature identification of ECG signal is found highest in wavelet transform. The Hilbert transform and Hadamard transform give good accuracy in feature identification and also capable of detecting atrial fibrillation, QRS complex in weak ECG signal.

TABLE I
Comparative study of various transform

Transforms	Purpose of Study	Accuracy	Limitations
Fast Fourier Transforms.	1. R-Peak detection in ECG signal 2. S Peak detection in ECG 3. Heart Rate computation	98.48 % (Feature Identification)	Artificial neural network data set required for training
Wavelet Transforms.	1. Arrhythmia classification of ECG signal 2. QRS- complex detection 3. Motion artifacts removal of ECG signal	99.92 % (Beat Detection)	Not quantified
Laplacian based-Karhunen-Loeve transform.	1. Ischemic event detection	Improved accuracy	Single investigation
Hilbert Transform.	1. QRS Detection 2. Weak ECG signal Detection	Average detection accuracy of 99.80	Not Quantified
Hadamard Transform	1. Atrial Fibrillation detection	99.3% (With LMNN classifier)	Not Quantified

V. Conclusion

The synergy between mathematics and biomedical sciences has yielded multifaceted benefits. Accurate diagnoses, personalized treatment strategies, and innovations in medical device design emerge as tangible outcomes of this integration. The ability to translate complex signal information into a visual and quantifiable format empowers medical professionals to make informed decisions, while also offering a foundation for groundbreaking research and exploration.

Yet, this journey is not without its challenges and ongoing quests. The ever-evolving landscape of biomedical sciences demands a continuous refinement of mathematical expressions, signal processing techniques, and their application. Collaborations between mathematicians, engineers, and medical experts remain crucial for pushing the boundaries of knowledge and technology, leading to more precise diagnostic tools and improved patient care.

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