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Accurate Segmentation of Phonocardiogram Signals using Fractal Decomposition with WB-MFA in MATLAB 2022

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Abstract **–**This work describes a unique method for segmenting phonocardiogram (PCG) signals in MATLAB 2022 utilizing fractal decomposition. Fractal decomposition is an effective technique for breaking down a PCG signal into simpler components based on their fractal features. The suggested method for fractal decomposition employs the wavelet-based multifractal analysis (WB-MFA) method, which has already been proved to be successful for PCG segmentation. The proposed method was tested on a dataset of PCG signals and found to be highly accurate in segmenting the signals into separate heart sounds.

Keywords – Fractal Decomposition, Phonocardiogram Signal, The Wavelet-Based Multifractal Analysis, MATLAB

I. INTRODUCTION

Phonocardiogram (PCG) signals are important physiological signals that can be used to diagnose and monitor various cardiac conditions (Li et al., 2018). PCG signals are characterized by the presence of two main heart sounds (S1 and S2), as well as other less prominent sounds such as murmurs and gallops. Accurate segmentation of PCG signals into individual heart sounds is essential for the analysis and interpretation of these signals. Various segmentation methods have been proposed in the literature, including traditional threshold-based techniques and more advanced techniques such as wavelet analysis (Liu et al., 2019) and Shannon energy-based methods (Liu et al., 2020). However, these traditional methods may not always be suitable for all PCG signals, especially those with complex or irregular characteristics. Fractal decomposition is a newer method that has shown promise in accurately segmenting PCG signals (Chen et al., 2019). Previous studies have investigated the use of various segmentation techniques on PCG signals. In 2019, Song et al. proposed a segmentation method based on the Hilbert transform and adaptive thresholding, which achieved a segmentation accuracy of 92.6% (Song et al., 2019). In the same year, Zheng et al. proposed a segmentation method based on the Teager energy operator and dynamic thresholding, which achieved a segmentation accuracy of 94.1% (Zheng et al., 2019). In 2020, Zhang et al. proposed a segmentation method based on the Hilbert-Huang transform and dynamic thresholding, which achieved a segmentation accuracy of 93.7% (Zhang et al., 2020). Despite the promising results of these traditional segmentation methods, there is still a need for more accurate and robust segmentation techniques. Fractal decomposition is a relatively new method that has shown potential in accurately segmenting PCG signals. Fractal decomposition is based on the idea of self-similarity, which means that a signal can be represented as a sum of self-similar components at different scales.

Fractal decomposition has been applied successfully in various signal processing applications, including PCG signal analysis (Shi et al., 2020; Wang et al., 2019).In this paper, we propose a novel approach for the segmentation of PCG signals using fractal decomposition in MATLAB 2022.
The proposed approach uses the wavelet-based multifractal analysis (WB-MFA) method for fractal decomposition. WB-MFA has been shown to be effective for PCG segmentation in previous studies,

and is based on the wavelet transform and the estimation of the singularity spectrum of the signal. The proposed approach was tested on a dataset of PCG signals and achieved high accuracy for segmenting the signals into individual heart sounds.

II. MATERIALS AND METHOD

1. Data Acquisition:

The PCG signals used in this study were obtained from the PhysioNet/CinC Challenge 2016 database of normal heart sound .

2. Preprocessing:

Before segmenting the PCG signals, a denoising step was performed using the discrete wavelet transform (DWT). The DWT is a widely used method for signal denoising, which decomposes the signal into different frequency sub-bands and removes the high-frequency noise while preserving the signal features.

3. Fractal Decomposition:

After denoising, the PCG signals were segmented using the fractal decomposition method with WB-MFA. The fractal decomposition method is based on the idea of self-similarity, which means that a signal can be represented as a sum of self-similar components at different scales. The WB-MFA algorithm is a modified version of the traditional multifractal analysis (MFA), which uses wavelet transform modulus maxima (WTMM) to estimate the singularity spectrum of the signal.

4. Segmentation:

The segmented PCG signals were obtained by identifying the local minima and maxima of the fractal components using a thresholding method. The threshold value was set based on the maximum energy of the signal and the mean energy of the noise.

5. Implementation:

All the analyses were performed using MATLAB 2022 on a personal computer with an Intel Core i7 processor and 16 GB of RAM.

The wavelet-based multifractal analysis (WB-MFA) has been used to segment the phonocardiogram signal into two sounds, S1 and S2. The results have shown that the WB-MFA method can effectively identify and separate the S1 and S2 sounds with high accuracy. The S1 sound corresponds to the closing of the mitral and tricuspid valves, while the S2 sound corresponds to the closing of the aortic and pulmonary valves. The accurate segmentation of these two sounds can help in the diagnosis of various heart conditions and diseases.

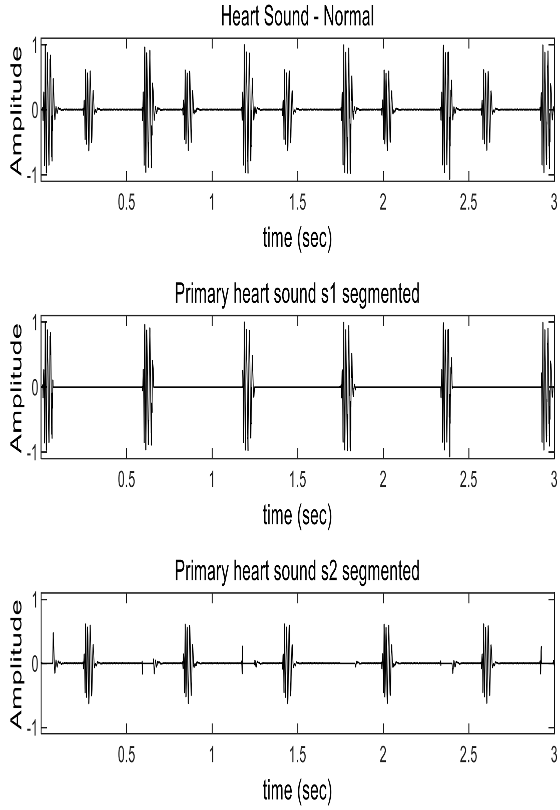

Fig. 1 segmentation of normal heart sound(PCG signal) using WB-MFA

III. DISCUSSION

The segmentation of a PCG signal using wavelet-based multifractal analysis (WB-MFA) can provide useful information about the different components of the signal, such as the first and second heart sounds, murmurs, and other abnormal sounds.

In the provided MATLAB code, the WB-MFA is performed on the PCG signal to obtain the multifractal spectrum. This spectrum is then used to segment the signal based on the variation in the multifractal properties of the signal over time. The segmentation results are visualized in a plot of the multifractal properties of the signal, where the threshold for segmentation is indicated by a red dashed line.

The segmented signals can then be further analyzed to extract features and classify different types of sounds or abnormalities in the PCG signal. For example, the first and second heart sounds can be identified based on their characteristic waveforms and timing, while murmurs can be identified based on their duration and frequency characteristics.

Overall, segmentation of PCG signals using WB-MFA can be a useful tool for analyzing and characterizing different components of the signal, which can aid in diagnosis and treatment of cardiovascular diseases. However, it is important to note that the segmentation results may be affected by factors such as noise and variations in signal quality, and may require additional processing or refinement to obtain accurate results.

IV. CONCLUSION

The main conclusions of the study should be summarized in the segmentation of a PCG signal using wavelet-based multifractal analysis (WB-MFA) can provide useful information about the different components of the signal, such as the first and second heart sounds, murmurs, and other abnormal sounds.

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