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Exploring the Application of Vibration Analysis Technology in the Medical Field

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Abstract

In the field of engine maintenance and assurance, the technology of unit condition detection through vibration analysis is relatively mature. More and more patents and technical products have been released, proving the practical value of the technology in mechanical vibration from the application level. In medical science, signals such as heart sounds and pulses are also vibration signals in nature, in order to expand the application of the technology and explore the value of the technology in medical applications. In order to extend the application of the technology and to explore the value of the technology in medical applications, the wavelet analysis technology was used to program the Labview2022 software to implement the corresponding analysis program for the analysis of the collected physiological signals. Finally, the wavelet transform-based analysis of the physiological signals was successfully implemented. It is demonstrated that the design concept can be achieved by applying this technique, which makes it valuable in the field of physiological signal detection and analysis.

Keywords

Vibration, Physiological Signal, Analysis, Wavelet Technique, Detection

1. Introduction

In the field of engine maintenance, the technology of vibration analysis for unit condition detection has been relatively mature, and more and more patents and technical products are available, which prove the practical value of the technology in mechanical vibration from the application level [1]. In medicine, the nature of signals such as heart sounds and pulses is also vibration signals, in order to extend the application of the technology and to explore the value of the technology in medicine.

For the work of signal analysis and research, it is often difficult to use a single method to achieve the purpose of comprehensive and objective research, and it will show its own disadvantages when analyzing the signal of a specific condition, so here the integrated analysis method of wavelet transform is introduced in order to achieve the desired purpose [2] [3], that is, in order to achieve effective display and assisted identification of physiological vibration signals with the help of advanced signal analysis techniques.

LabVIEW2022 was used to design the system and the human heart sound signal was used as the microacoustic signal for experimental analysis.

2. Functional Design and Principle of the System

2.1. The Design of System Function

The wavelet transform window changes with the change of frequency to adapt to it, incorporating the idea of Fourier local transform, which can highlight the characteristics of the corresponding aspects flexibly through the transform, and is more utilized for the analysis of the signal [4].

In view of its various excellent properties, this experiment introduces: the DWT (discrete wavelet transform) multi-resolution analysis method; the multi-resolution wavelet analysis method; and the WA resolved wavelet transform method, which are three types of methods, and the functional design diagram of the system can be seen in **Figure 1**. **Figure 1** shows the design style of the whole system, and this experiment really demonstrates the signal processing part of the system.

2.2. Principle of the System

A multi-resolution discrete wavelet transform (DWT) analysis can be expressed in the following concrete form [5]: let $\{V_j\}$ be a series of closed subspaces in $L^2(R)$, $j \in Z$. To call $\{V_j\}$, $j \in Z$ a multi-resolution analysis, the following six conditions must be satisfied simultaneously:

1) $\forall (j,k) \in Z^2$, $x(t) \in V_j$, then $x\left(t - 2^j k\right) \in V_j$;

2) $\forall j \in Z, v_j \supset v_{j+1}, \cdots V_0 \supset V_1 \supset \cdots v_j \supset v_{j+1} \cdots$;

3) $\forall j \in Z$, if $x(t) \in V_j$, then $x\left(\frac{t}{2}\right) \in v_{j+1}$;

4) $\lim\limits_{j \to \infty} V_j = \bigcap\limits_{j=-\infty}^{\infty} V_j = \{0\}$;

5) $\lim\limits_{j \to \infty} V_j = Closure\left(\bigcup\limits_{j=-\infty}^{\infty} V_j\right) = L^2(R)$;

6) $\forall \theta(t)$, let $\{\theta(t-k)\}$ be the Riesz base in V_0, $k \in Z$.

$$\Psi(t) = \sqrt{2} \sum\nolimits_{n \in Z} h_n \phi(2t - n) \tag{1}$$

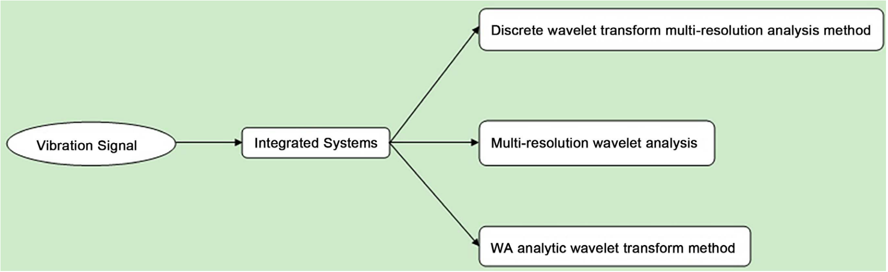

Figure 1. Functional design diagram of the analysis system.

h_n is the scale function. Based on this, the relationship between the scale function and the wavelet mother function can be understood by the above analysis, where g_n is the coefficient derived from h_n [6].

$$\Psi(t)=\sqrt{2}\sum\nolimits_{n\in z} g_n\phi(2t-n) \tag{2}$$

The translational representation of $\Psi(t)$ is $\psi_{j,k}(t)$; $p_L(t)$ is the translational representation of the ruler function $\text{p}(\text{t})$, and any $f(t)\in L^2(R)$ can be decomposed and expressed as:

$$f(t)=\sum\nolimits_{k\in Z} c_k p_L(t)+\sum\nolimits_{j<J,k\in Z} d_{j,k}\psi_{j,k}(t) \tag{3}$$

$$c_k=\int_R f(t)p_L(t)\text{d}t;\ d_{j,k}=\int_R f(t)\psi_{j,k}(t)\text{d}t \tag{4}$$

The resolution of the wavelet analysis is controlled by the parameter *J*.

The analytic wavelet transform method, abbreviated as WA, is a special case of continuous wavelet transform with complex-valued Morlet wavelets, also known as Gabor wavelets, and the desired transform model can be constructed using CWT [7] [8]. Where the Morlet wavelet is:

$$\phi_0(t)=\frac{1}{\sqrt[4]{\sigma^2\pi}}\exp\left(-\frac{t^2}{2\sigma^2}+jw_0t\right) \tag{5}$$

3. Application Verification

The system can be used with a variety of types of wavelets, and this experiment uses the db02 wavelet as an example for demonstration.

The results are shown in **Figure 2** and **Figure 3**. **Figure 2** shows the heart sound signal of a normal person after the joint time-frequency analysis; **Figure 3** shows the heart sound of a patient with mitral stenosis after the analysis.

The difference between the normal signal and the case signal after wavelet transform analysis is already visible by comparing **Figure 2** with **Figure 3**, and will be explained separately by sub-functional module afterwards.

The signal profiles after the discrete wavelet transform multi-resolution analysis method processing can be seen through **Figure 4** and **Figure 5**.

By comparing **Figure 4** with **Figure 5**, the difference in the graphical characteristics of the normal heart sound signal and the abnormal heart sound signal can be seen, which qualifies as an aid to diagnosis.

Figure 6 and **Figure 7** show the heart sound signal profiles after processing using multi-resolution wavelet analysis.

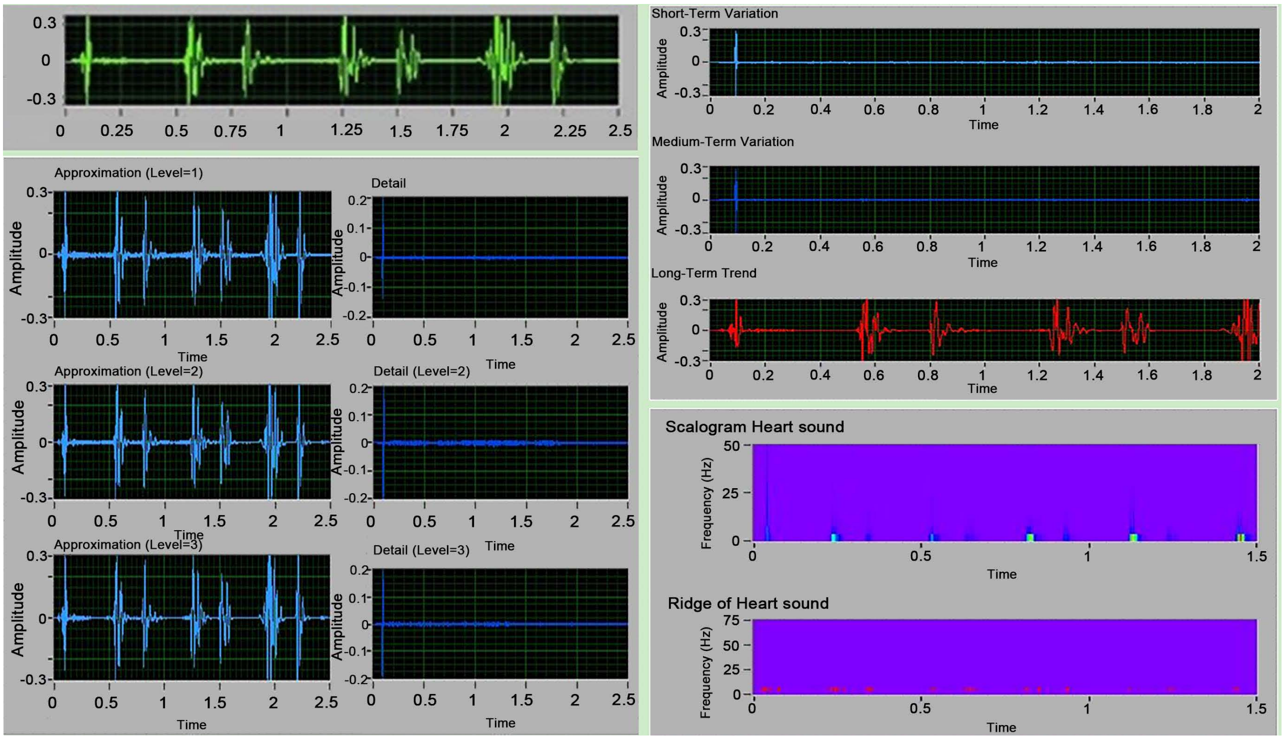

Figure 2. Heart sound atlas of a normal person.

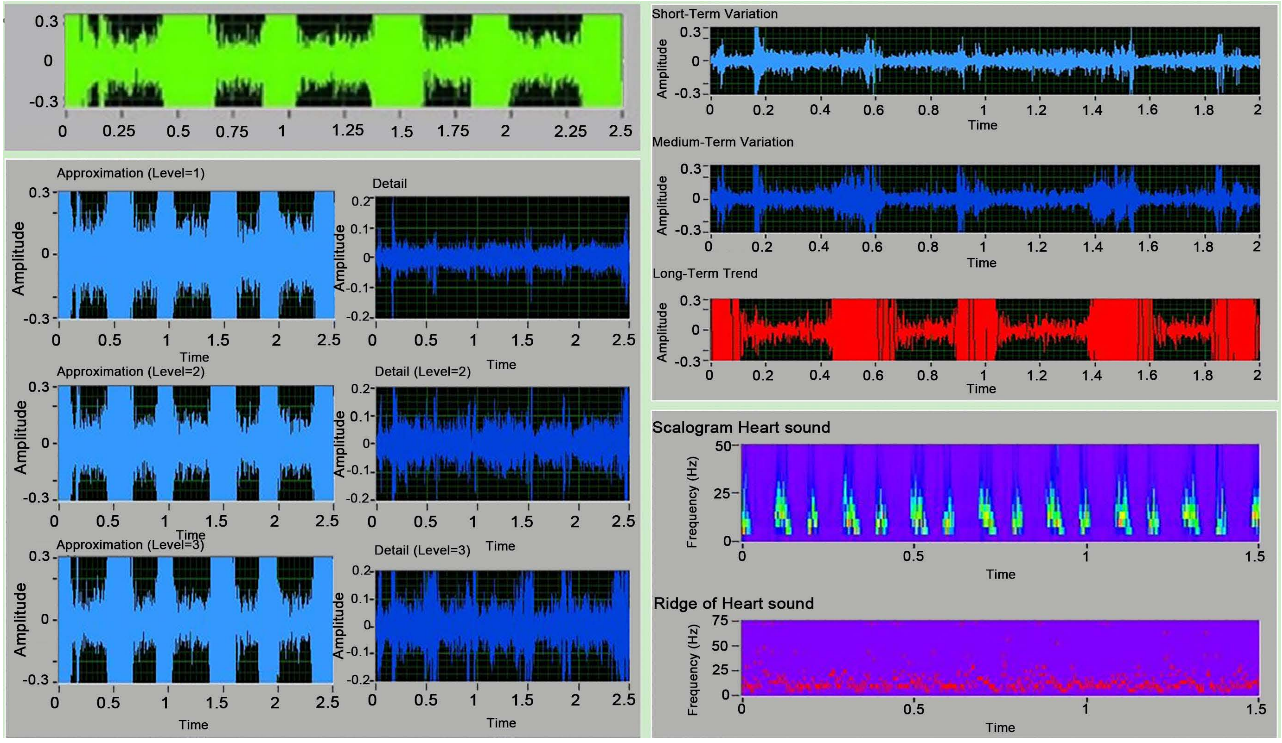

Figure 3. Atlas of heart sounds in patients with "mitral stenosis".

The contrast between the heart sounds of a normal person and a patient with mitral stenosis after multi-resolution wavelet analysis can be seen in Figure 6 and Figure 7, and can be used as a basis for determining the disease.

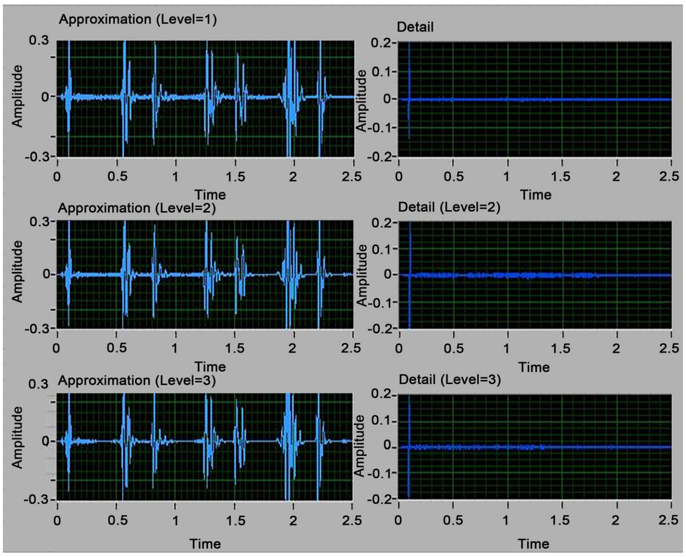

Figure 4. Analysis of normal heart sounds by discrete wavelet transform multi-resolution analysis.

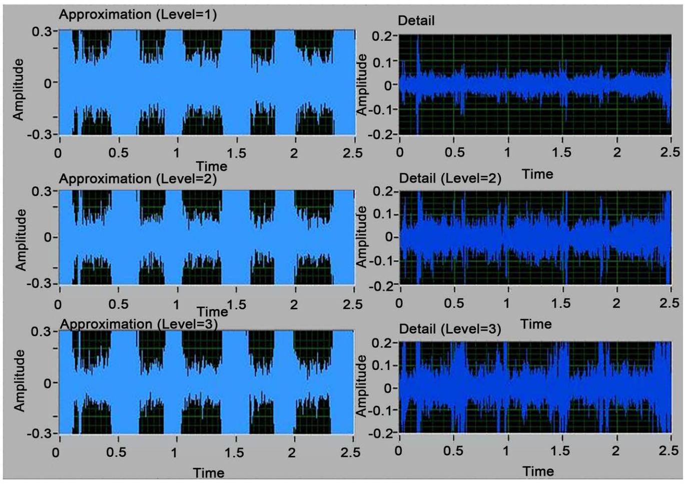

Figure 5. Discrete wavelet transform multi-resolution analysis of heart sounds in cases.

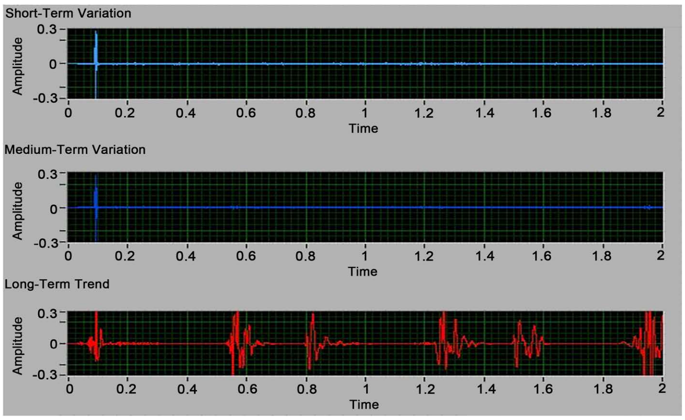

Figure 6. Analysis of normal heart sounds by multi-resolution wavelet analysis.

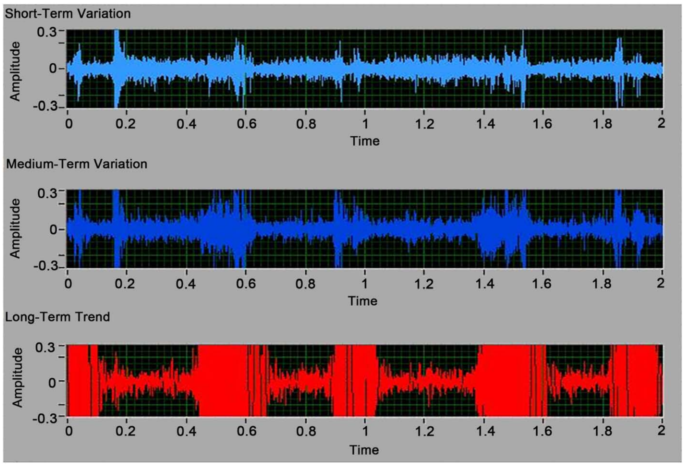

Figure 7. Heart sounds of cases analyzed by multi-resolution wavelet analysis.

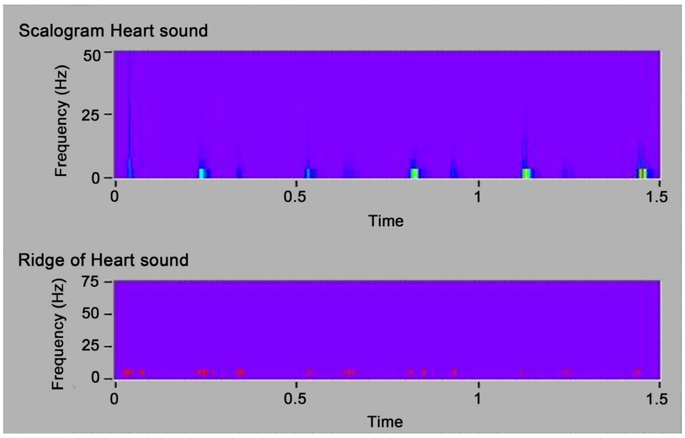

Figure 8. Analysis of normal heart sounds by wavelet transform method.

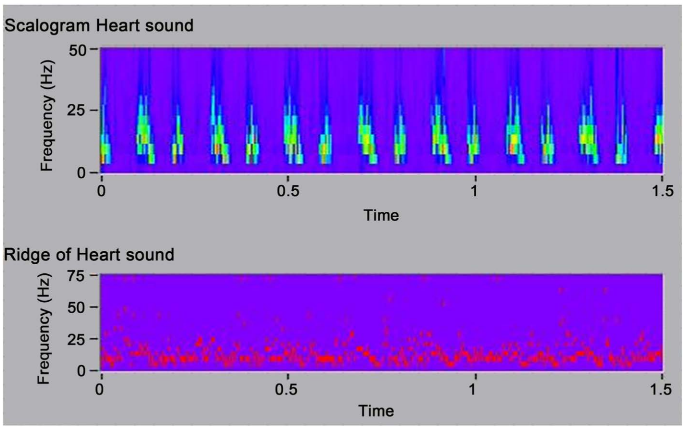

Figure 9. Analysis of heart sounds of cases by wavelet transform method.

Figure 8 and Figure 9 show the heart sound signal profiles after processing using the WA analytic wavelet transform method.

Figure 8 and **Figure 9** show a comparison between the heart sounds of a normal person and a patient with "mitral stenosis" after processing by the analytic wavelet transform method. The graphical display makes it easier and more feasible to determine the corresponding characteristics and improves the recognition of the disease characteristics.

4. Conclusions

Through the analysis of the above-mentioned figures, it can be seen that all the designed sub-functions can be successfully implemented, and the system can be flexibly set for detailed analysis of different processing requirements.

The micro-acoustic signal analysis system based on wavelet transform method is successfully applied to the analysis of complex physiological signals by LabVIEW2022, and achieves the expected goal, which will be designed as a part of a comprehensive analysis system for corresponding integration.

The successful application of this technology will help improve the accuracy of auscultation. It is expected that in the future, small-scale integrated physiological signal analysis devices equipped with such technology will be available, making medical diagnosis more informative and intelligent.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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