A threshold research for de-noising operation to the vibration signals based on wavelet package

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Abstract. Vibration signals are often interfered by salt and pepper noise, impulse noise, Gaussian noise, and other high-frequency noise, affecting the effect of vibration control research. Therefore, de-noising operation is significant for vibration signal in the practical engineering. In order to resolve this problem, wavelet package is used to remove noises from vibration signal. We provide the principle of de-noising method based on wavelet package at first. And then, the threshold selection of the method is analyzed by a vibration signal with noises. As the result shown, the noise can be effectively eliminated. This reflects that the de-noising method based on wavelet package with the hard threshold is effective.

1. Introduction
In structural vibration research, signals used for theoretical research are inevitably contaminated by high-frequency noise during the acquisition process. These noises usually affect the response, and the presence of high frequencies may affect the accuracy and robustness of structural vibration. Therefore, the signal can be de-noised before the structural vibration study. Wavelet analysis, as a time-frequency analysis method, overcomes the shortcomings of Fourier analysis, and it goes without saying that, except for periodic excellent signals and stationary signals. So wavelet is widely used in signal processing in engineering [1-4]. There are almost no other processing tools in signal processing is comparable to wavelet analysis [5-6].

2. The principle of de-noising method based on wavelet package
Applying wavelet packet analysis to de-noise the signal is a basic function of it. In general, follow these steps:
   (1) Wavelet packet decomposition of signals. Select a wavelet and determine the levels that need to be decomposed, then perform wavelet packet decomposition on the signal.
   (2) Determine the optimal wavelet packet basis. For a given entropy standard, the optimal tree is calculated (this step is not necessary and can be used selectively depending on the purpose).
   (3) Threshold quantization of wavelet packet decomposition coefficients. For each wavelet packet decomposition coefficient, an appropriate threshold is selected and the coefficients are threshold quantized.
(4) Signal wavelet packet reconstruction. According to the lowest layer wavelet packet decomposition coefficients and quantized processing coefficients, wavelet packet reconstruction is performed.

Among the above steps, the most critical is how to select the threshold and how to quantify the threshold. To a certain extent, they are directly related to the quality of signal de-noising.

3. The testing signal
In order to verify the effectiveness of the method, a testing signal is introduced, and the sampling frequency is 1 kHz. The time series figure of the signal is shown in fig.1. As can be seen in the fig. 1, the energy of noise is high.

![Figure 1. The time series figure of x signal with noises](image)

4. Analysis of the threshold
The wavelet package is used to process the signal, and the global threshold is firstly adopted (the global threshold is 4.29), as shown in fig. 2. As can be seen in fig. 2, some noise is removed from the signal, however, some noise is kept. After that, we increase the threshold to 9.29, 14.29, 19.29, 24.29 and 29.29, as shown in figs. 3-7. As can be seen in figs. 2-4, more and more noise is eliminated from the signal, as the threshold increases. As shown in figs. 4 and 5, the signals are similar. This reflect that all the noise can be almost removed from the signal, when the threshold is within a certain range. As shown in figs. 6 and 7, some noise is kept in the signal. As indicated in figs. 2-7, the threshold selection is important for de-noising effect.

![Figure 2. The de-noising signal with the global threshold.](image)
Figure 3. The de-noising signal with a threshold of 9.29.

Figure 4. The de-noising signal with a threshold of 14.29.

Figure 5. The de-noising signal with a threshold of 19.29.
5. Conclusion

In order to eliminate noise from the vibration signal, the wavelet package is introduced in this paper. At first, the principle of the algorithm is illustrated, and the specific decomposition process is elaborated. The method is applied to a signal, which contain harmonic components and noise. It can be concluded that the result shows that the noise can be effectively eliminated by using this method with a reasonable threshold.

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