Modal Parameter Statistical Identification Based on Improved Random Decrement Technique and Wavelet Transform

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Summary

This paper presents a new statistical identification method for modal parameter based on improved random decrement technique and wavelet transform. Improved random decrement technique can make a direct deal with zero-mean non-stationary signals for free decay responses. The time-frequency characteristics of the wavelet transform can decouple dense frequency and low damping system. The bootstrap procedure is employed to evaluate and decrease the uncertainty of identification results. A complete theoretical derivation is proposed and a numerical example which is a four-degree-of-freedom system is used to illustrate the reliability of the proposed method. Compared with the traditional time-domain method and the wavelet transform only method, the presented method has higher recognition accuracy, especially for damping ratio coefficients.

Keywords: modal parameter identification; improved RDT; wavelet transform; Bootstrap method; noise resistance.

1. Introduction

Modal parameter identification is an important field of structural dynamics. It is a significant precondition for structural damage detection, finite element model updating and state assessment. Modal parameters of large structures are always determined through measuring and estimating from the real structural dynamic responses. Traditional modal parameter identification methods include frequency domain methods (Peak-Picking method, enhanced frequency domain decomposition method and so on) and time domain methods (Ibrahim technique decomposition, eigenvalues realization method, stochastic subspace identification and so on). However, these traditional methods apply only for stationary signals and are very sensitive to noise. Many restrictions exist for their application to non-stationary signal processing.

This paper proposes a statistical modal parameter identification method based on improved random decrement technique and wavelet transform (IRDT-Bootstrap-WT). The method is mainly composed of the improved random decrement method, bootstrap theory and wavelet transform. Improved random decrement technique allows to deal with zero mean non-stationary signals directly for free decay responses. Wavelet transform decouples dense frequency and low damping ratio system in time-frequency domain. Bootstrap theory considers and reduces the estimation uncertainties of parameters induced by some previous mentioned factors. Theoretical analysis and numerical example are used to verify the reliability of the proposed method.

2. Basic theory

Fig. 1 show the entire scheme of the new parameter identification method IRDT-Bootstrap-WT.

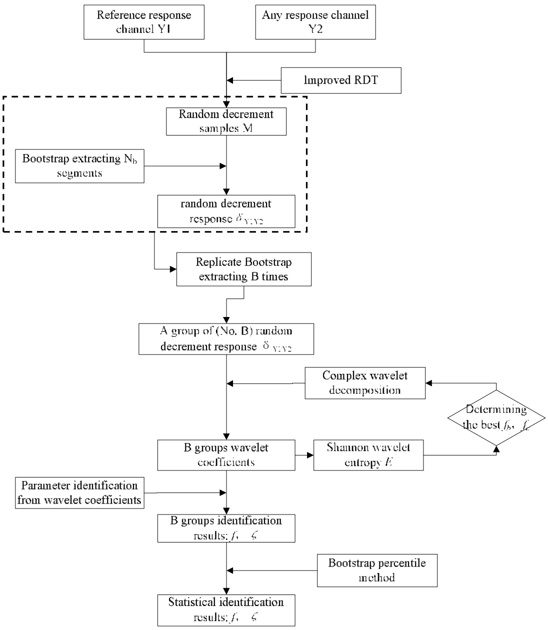

Fig. 1: Scheme of the parameter identification method IRDT-Bootstrap-WT

3. Numerical validation

Numerical example is a four-degree-of-freedom system. White noise exctiation is applied on each mass point of the system. Three methods are used and compared with each other for modal parameter identification of the system. They are the proposed method (IRDT-Bootstrap-WT), wavelet transform only method (WT-Only) and traditional time domain method RDT-ITD. Estimation results indicate that the maximum error of the identified natural frequencies is 0.26% and of the damping ratios is 4.08% (second-order mode) using the proposed method. Compared with the other two methods, the proposed method has a higher identification accuracy, especially for the damping ratio of the system. The maximum identification errors of the damping ratios reach 34.62% (WT-Only) and 42.31% (RDT-ITD) respectively.

4. Conclusions

This paper proposes a new statistical identification method for modal parameters combined with improved random decrement technique, bootstrap theory and wavelet transform. The proposed method is verified by theoretical analysis and numerical example. Note that the proposed method is able to estimate the natural frequencies and the damping ratios of the system precisely, which avoids the deviation caused by stationary assumption and decreases the uncertainty using bootstrap mean value. Compared with traditional parameter identification methods, the proposed method has a higher identification accuracy, especially for the damping ratio. In the practical application of the proposed method, identification results using different reference points can be validated by each other in order to further improve the reliability of the estimation results.

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