8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

A NEW OUTPUT-ONLY MODAL SPACE FRAMEWORK TO IDENTIFY CLOSELY-SPACED MODES AND STRUCTURAL MASS DISTRIBUTION USING BLIND SOURCE SEPARATION

Alireza GHAFOURI
PhD. Candidate, IIEES, Tehran, Iran
alireza.ghafouri@iiees.ac.ir

Hossain JAHANKHAH
Assistant Professor, IIEES, Tehran, Iran
h.jahankhah@iiees.ac.ir

Keywords: Output-Only System Identification, Blind Modal Identification (BMI), Time-Frequency Distribution (TFD), Mass Distribution Approximation, Closely-spaced mode

In recent years, the advent of output-only methods helps researchers to overcome the difficulties and costs of measuring input-motions during identifying structural systems. Blind Source Separation (BSS) is a prominent approach, which is based on output measurements of structure. Blind modal identification (BMI) is one of the byproducts of this method for structures when there is lack of information about inputs. In this paper, a new framework introduced to identify the modal properties of two various synthetic 3-dof structures. The first one is a 3-Dof system with relatively well separated natural frequencies and the second one is a 3-dof system with closely-spaced modes. The advantages of this newly introduced method for identifying closely spaced modes and also finding an accurate approximation of mass distribution matrix of whole structure, are presented in this article. This method is a combination of time-frequency-based BMI and the governing equations in modal space (modal equations and orthogonality). This approach only uses the free vibration portion of measured sensors (i.e. absolute accelerations) on structure at the end of earthquake excitation to get full information about modal characteristics of structure. However, it should be noted that the effects of noise on responses are waived. The BMI in time-frequency context was first applied by Ghahari et al. (2013) for structural identification. Their work was based on a time-frequency distribution (TFD) named Wigner Ville. This TFD Distribution plays a key role in BSS. That method of BSS works on sparse components analysis in time frequency (TF) domain. The method also needs the sources to be disjoint. The disjoint sources can be simply defined as sources, which are not mixed in TF domain and aligned along a special frequency when they are mutually depicted in an identical plane of TF like figure1. They are usually without any overlap.

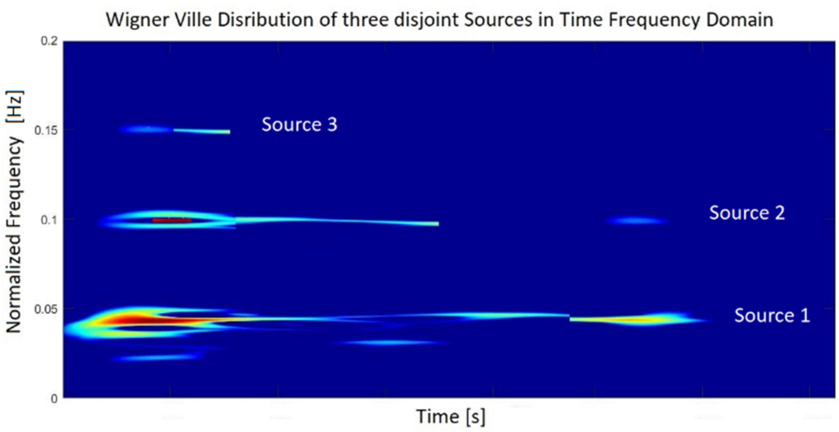

Figure 1. A typical sample of disjoint sources in time frequency (TF) plane.

Our sources in modal space are considered modal coordinates (absolute modal acceleration $\ddot{q}$) in two synthetic models and the results show that these sources are disjoint in the first case and non-disjoint in the case with closely spaced modes. However, we do not have any information about $\ddot{q}$ as modal coordinate. Thus, this identification is based on selecting candidate points on TF plane of outputs that has the information of only one source. These points are called single auto-term TF points. To select these candidate points, the proposed approach of Févotte and Doncarli (2004) can be used and the (t,f) points can be found where the STFD matrices verify specific conditions. A sample of these selected points for each case is shown in Figure 2. As it can be seen, in case two, the location of second and third mode along frequency axis, are mixed and the distinction is not obvious. Therefore, in the closely spaced mode synthetic model, two sources are non-disjoint. There are supplementary methods like the one introduced by Aïssa-El-Bey et al. (2007) for this case, through sophisticated procedures with limited accuracy. Here, a simple framework is presented based on modal space equations and relations that can properly substitute those elaborate methods. The final results for system after applying this procedure are presented in Tables 1 and 2. As can be seen most of prediction errors in natural frequency, damping, mass matrix and mode shapes do not reach %1. The damping of the third mode in the first case is an exceptional which shows an error about 14%.

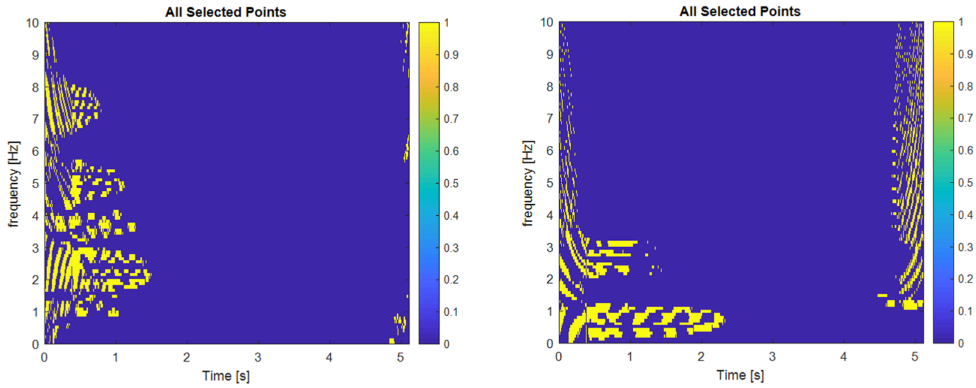

Figure 2. Comparison between candidate points in two cases at the end of Free Vibration Portion- (a) Simple 3-Dof, (b) Closely Spaced Mode Case.

Table 1. The accuracy of approximated mass matrix distribution and also first and third Mode's Damping Rations.

Model	M0 (User Defined)	Approximate Mass Matrix	Error in Mass Distribution and Exact (%)	Damping Ratios	Error in Damping Ratio (%)
Case 1	$\begin{bmatrix}1\\1.47\\2.13\end{bmatrix}$	$\begin{bmatrix}1&0&0\\0&1.52&0\\0&0&2.02\end{bmatrix}$	$\begin{bmatrix}0\\+1\%\\+1\%\end{bmatrix}$	$\xi_1 = .05$ $\xi_3 = .043$	0% 14%
Case 2	$\begin{bmatrix}1\\1.18\\0.93\end{bmatrix}$	$\begin{bmatrix}1&0&0\\0&1.01&0\\0&0&1.01\end{bmatrix}$	$\begin{bmatrix}0\\+1\%\\+1\%\end{bmatrix}$	$\xi_1 = .05$ $\xi_3 = .0496$	0% 0.8%

Table 2. Comparison of the identified values of frequency and Mode shapes.

Model	Identified Freq.[Hz]	Error in Freq. (%)	Calculated Mode Shapes	Error in Mode Shape (%)
Case 1	2.3095 4.9261 7.2993	0.005% 0.2% 0.41%	$\begin{bmatrix}0.8135&-0.74&0.2622\\0.5272&0.45&-0.6908\\02457&0.49&0.6738\end{bmatrix}$	$\begin{bmatrix}0.01\%&0.07\%&3.96\%\\0.05\%&0.32\%&0.46\%\\0.07\%&2.4\%&1.15\%\end{bmatrix}$
Case 2	0.4998 2.5381 2.6954	0.04% 0.07% 0.17%	$\begin{bmatrix}0.0586&-.71&0.7034\\0.6749&-0.49&-0.5512\\0.7356&0.50&0.4488\end{bmatrix}$	$\begin{bmatrix}-0.46\%&0.89\%&0.69\%\\0.03\%&0.56\%&0.91\%\\0.02\%&2.30\%&0.35\%\end{bmatrix}$

REFERENCES

Ghahari, S.F., Abazarsa, F., Ghannad, M.A., Çelebi, M., and Taciroglu, E. (2013). Blind modal identification of structures from spatially sparse seismic response signals. *Structural Control and Health Monitoring*, doi:10.1002/stc.1593.