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TIME DOMAIN MODAL PARAMETER ESTIMATION METHODS USED IN OMA: A COMPARISON

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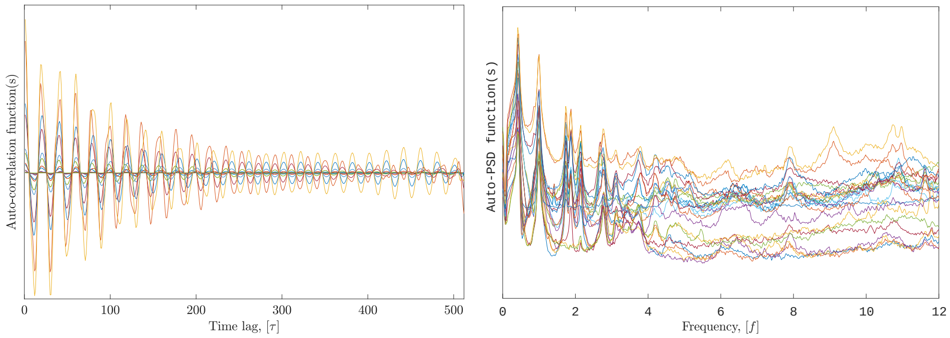
MOTIVATION

Within the field of Operational Modal Analysis (OMA) it is sought to estimate modal parameters that are consistent. Modal Parameter Estimation (MPE) methods that operate in the time domain have shown to perform well in OMA. However, it is not apparent whether MPE methods that adopt a low or high matrix polynomial order perform better over one another, or if they result in the same estimates of modal parameters. In this extended abstract, the modal parameter estimates computed from two such extremes are compared. The MPE methods used are the multi-reference Ibrahim Time Domain (MITD) method (similar to cov-SSI) and the Modified multi-reference Ibrahim Time Domain (MMITD) method (similar to PTD). To minimize inconsistency in decisions made from an operator, an Automated OMA algorithm is applied. Data from a research platform located in the North Sea (Fino3) have been processed and the results presented. The modal parameter estimates from the two MPE methods are discussed.

RELEVANT RESULTS

The data set processed corresponds to 3600 seconds of structural response measured from 24 accelerometers that were distributed on the platform. The lowest natural frequency was found to be $0.42\,Hz$, which allows approximately 1500 cycles of the first natural frequency in one data set. An unbiased estimator was used to compute the correlation functions using a block-size of 512 samples. In Figure 1 the (auto) correlation functions and (auto) power spectral density functions are shown. The (auto) correlation functions may be treated as free decay functions. The functions seem to decay after 250 time lag values. Furthermore the amplitude of some of the functions are significantly higher than others. By looking at the (auto) power spectral density plots it is quite obvious that there is a peak around $0.42\,Hz$ and a peak around $1.0\,Hz$ as well as a few peaks just below $2.0\,Hz$. Also, a few peaks are seen above $2.0\,Hz$. Only modes below $2.0\,Hz$ are considered in the following.

The (auto) correlation functions shown are used as input in the MPE methods, i.e. the MITD and the MMITD methods. The former produces mode shapes directly, while the latter yields modal participation factors that are used together with the poles and correlation functions, to estimate mode shapes using a time domain least squares fit. The two MPE methods require a user to select a maximum order as well as how many time lag values of the correlation function that should be used. The maximum model order is chosen to be 40 (80 poles), while the number of time lag is set to 50. It is common to plot the model order as a function of the natural frequency to reveal stable poles. This is known as a stabilization



(a) (auto) correlation functions **(b)** (auto) power spectral density functions

Figure 1: (auto) correlation and power spectral density functions of the response data measured on Fino3

diagram, and is a useful tool to reveal physical poles. It is common to analyze such diagrams manually and select stable poles. However, this process is both time consuming and can be inconsistent. Therefore an automated algorithm for modal parameter estimation is used. The method was developed by the author and utilizes histogram analysis on the stabilization diagram to detect physical poles. This method also has a decision rule based on the modal assurance criterion (MAC) that ensures that poles in each bin are similar. The MITD method uses a low order matrix polynomial order, and the MMITD method uses a high matrix polynomial order. In the following we shall consider four scenarios, i.e. low order and high order normalization of the system equations for MITD and MMITD, respectively. See [1] for more details. A comparison of the mean frequency and mean damping ratio estimates can be seen in Table 1.

Table 1: Frequency and damping estimates using different Modal Parameter Estimation (MPE) methods and normalization of the system equations (Norm)

	MPE	Norm	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequency [Hz]	MITD	Low	0.420	0.430	0.992	0.997	1.741	1.874
	MITD	High	0.420	0.431	0.992	0.998	1.742	1.874
	MMITD	Low	0.420	0.431	0.992	0.997	1.741	1.874
	MMITD	High	0.420	0.431	0.992	0.998	1.742	1.874
Damping [%]	MITD	Low	2.017	2.230	1.087	1.038	0.525	0.881
	MITD	High	1.952	2.276	1.108	1.209	0.497	0.844
	MMITD	Low	2.038	2.176	1.081	1.042	0.528	0.882
	MMITD	High	1.947	2.240	1.103	1.192	0.496	0.835

It appears that the frequency estimates are unaffected by the MPE method used as well as the normalization of the system equations. For the damping ratio estimates, the two MPE methods yield distinct estimates and it appears that the normalization of the system matrices has an effect on the damping ratio estimates. Furthermore, some modes seems to be more affected than others.

CONCLUSIONS

Response data measured on the Fino3 platform have been used to estimate modal parameters using two different MPE methods. For each method, either a low order or a high order normalization of the system equations were used. The frequency estimates were consistent for all four scenarios. The damping estimates seemed to be affected by the MPE method used, it showed some sensitivity whether a low order or a high order normalization of the system equations were used. The mean values were based on around 60-80 estimates having a relative error lower than $1.5\ \%$. The MAC values of the estimates for each mode is above 0.99. Therefore, it can be concluded that for the current application and for the MPE methods used, a bias is introduced which depend on the normalization of the system equations. This should require further analysis. The work presented was supported by the INTERREG 5A Germany-Denmark program, with funding from the European Fund for Regional Development.

REFERENCES

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