Iterative Pole-Zero model updating for prediction of performance variables

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Prediction of unmeasurable performance variables in complex large-scale systems is an important topic in systems and control. For many systems in general and stage systems in the wafer scanning industry specifically, the performance variables can often not be measured at the location where the process takes place. In stage systems, the time-varying wafer position under the lens where wafer exposure occurs, is not accessible for direct measurement. High-precision stage systems need positioning accuracies at the sub-nanometer level. To achieve these accuracies, model-based control with generally highly accurate yet low-order standard plant models become increasingly important. A Finite Element (FE) dynamic model represents a complete standard plant model, but with the disadvantage that (a) it usually is of extremely high order which results in high demands on numerical processing capabilities and (b) it often cannot sufficiently match with the real structure.

To deal with the first problem, a reduced FE dynamic model that includes the residual flexibilities of truncated modes may be a good candidate. To deal with the second problem, an iterative procedure is proposed to update the reduced-order FE model using poles and zeros estimated from a few measured Frequency Response Functions (FRFs). The proposed methodology is referred to as Iterative Pole-Zero (IPZ) model updating, which aims at facilitating the process of obtaining improved dynamic models that can be used for accurate prediction of unmeasurable performance variables. In practice, few FRF measurements are obtained from the existing actuator/sensor configuration, thus no extra sensors will be used. For geometrically complex structures such as wafer stages, it may be far from trivial to identify which physical parameters are causing differences between the numerical and experimental quantities. In these situations, generic parameters may be better candidates for model updating. Assuming the errors in the FE stiffness and/or damping matrix to be dominant over the mass matrix, but the exact physical parameters responsible for these errors to be unknown, the eigenvalues of the (sub) structure stiffness and/or damping matrix can be updated to reduce the differences between the poles and zeros from the model and measured FRFs.