Reweighted $\ell_{2,1}$-Norm Regularization Approach for Identification of Linear Parameter-Varying Systems

Dora Turk, Joris Gillis, Goele Pipeleers and Jan Swevers
Department of Mechanical Engineering, KU Leuven, *Member of Flanders Make*, Belgium
Email: dora.turk@kuleuven.be

1 Methodology

Linear parameter-varying (LPV) systems are nonlinear systems described by a linear model with coefficients varying as a function of one or more scheduling parameters. A complex dependency on the scheduling parameter(s) complicates LPV control synthesis and analysis, which makes determination of an adequate dependency—described through some set of basis functions—an important issue in LPV system identification. In this paper, an automatic reduction of model structure complexity is accomplished by discarding redundant basis function dependencies from the state-space matrices through a reweighted $\ell_{2,1}$-norm regularization. Namely, the subsets of model parameters that do not substantially contribute to the system response are penalized heavily, while the significant subsets remain unaffected or are penalized only slightly. What follows is the experimental validation of the proposed regularized nonlinear least-squares-based identification approach on an XY-motion system.

2 Setup description

The XY-motion system shown in Fig. 1 consists of two perpendicularly mounted linear stages (X and Y) and a flexible cantilever beam. The cantilever beam resonances and hence the dynamics of the XY-motion system in the X-direction depend on the length of this beam, which is changed by the position of the Y-motor and considered to be the scheduling parameter. The reference velocity for the velocity controller of the X-motor is the system input, while the acceleration of the end-effector in the same direction represents the system output. Four local identification experiments, for different equidistant positions of the Y-motor were performed and the corresponding frequency response functions, evaluated at 385 equally distributed frequency lines of interest ($f \in [3, 50]$ Hz), form the identification data set.

3 Results

A 4th order discrete-time state-space LPV model parameterized with a 3rd order polynomial scheduling parameter dependency was first identified using the SMILE technique [1]. This model (G_{SMILE}) is then used to start the proposed regularized nonlinear least-squares identification, which yields a simpler scheduling parameter dependency

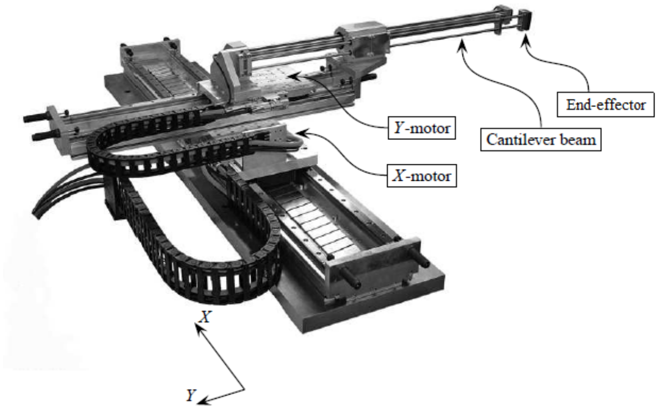

Figure 1: XY-motion system

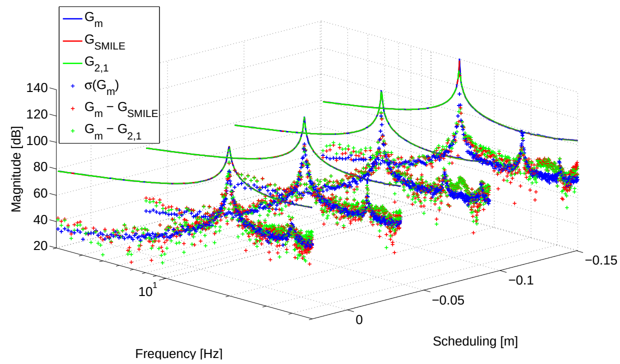

Figure 2: Local identification fit - magnitude.

($G_{2,1}$), in the sense that the input matrix and the complete output equation are independent of the scheduling parameter. Fig. 2 shows that both models reach a level of accuracy that is close to the maximal achievable accuracy, that is, the standard deviation of the measured system frequency response functions $\sigma(G_m)$. The obtained regularized model ($G_{2,1}$) gives a good compromise between the accuracy and simplicity.

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References

[1] De Caigny, Jan 2009. *Interpolating model identification for SISO linear parameter-varying systems*, Mechanical Systems and Signal Processing, Vol. 23, No. 8, Elsevier (2009), pp. 2395-2417.