Evaluation of Input Designs for MIMO System Identification Using Subspace Identification

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Abstract: It is desirable to make the identification procedure (equally) informative for all relevant directions through explicit input excitations. Due to the directionality properties, there may be difficulties in exciting the various directions adequately. In addition to that the ill-conditioned systems are inherently difficult to control. Hence identification and modeling of ill-conditioned MIMO (multiple-input multiple-output) systems is a challenging task.

It has been found that decent information about the high-gain direction is easier to obtain than the low-gain direction. Therefore, explicit excitation is required to obtain a model including the low-gain properties; otherwise, it may be inadequate for control design (Häggblom and Böling, 1998). Typically PRBS (pseudo-random binary sequence) signal is used for perturbing a system though, in recent years, many have argued multi-sinusoidal signal has more potential to act as a plant-friendly excitation than uncorrelated PRBS (Rivera et al. 2002).

Consider a singular value decomposition of the gain matrix, i.e. $y = Gu = U\Sigma V^T u = \sum_{i=1}^{n} U_i \sigma_i V_i^T u$, where the input $u = u^i = V_i \sigma_i^{-1}$ will produce the output $y = y^i = U_i, \left\| y^i \right\| = 1$. To properly excite all directions $i,\ i = 1, 2, \ldots n$, we need to apply inputs u^i that vary (symmetrically) between $u_-^i = -\sigma_i^{-1} V_i$ and $u_+^i = +\sigma_i^{-1} V_i$. This can achieve by any kind of input signals (step sequence, PRBS or multi-sinusoidal). Although, common practice is to use the uncorrelated PRBS signals for input excitation one at a time or simultaneously, this cannot excite the system in all directions adequately, especially in low-gain direction (Häggblom and Böling, 1998). Thus, it will be interesting to study the effect of directionality properties over the standard input designs for MIMO system identification. We have investigated to what extent the directionality problems can be reduced by the sophisticated input excitations for case studies (MIMO systems) taken from literature. Excitations can introduce one direction at a time or all directions simultaneously. For a 2x2 system we have low and high gain directions. However, for a system with more number of inputs and outputs (i.e. 3x3 or higher), there are more gain directions. Six different types of input excitations have been studied here. The designed input excitations are Sequential (one at a time) step change, Sequence of steps in all gain directions, Sequential PRBS in inputs (one at a time), Simultaneous uncorrelated PRBS in inputs, Sequential PRBS in all gain directions, Simultaneous PRBS excitation in all gain directions. In case of PRBS inputs, design guidelines given by Rivera et al. (2002) have been used as a starting point. Subspace identification has been used for modeling. Subsequently the quality of the models, and thus the quality of associated input excitation, has been evaluated by cross validations. We found the models evaluated from experiments where the directionality issues were not considered perform poorly compare to the experiments where directionality have been taken into account, especially in the low-gain directions.

Keywords: identification, experiment design, gain directions, input design.