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Data-based experiment design to maximize information for MIMO system identification

Keywords: system identification, multivariable system, ill-conditioned system, experiment design, data-based design

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Extended abstract. A problem in the identification of multiple-input multiple-output (MIMO) systems is that the system outputs in an identification experiment may be strongly correlated if the inputs are perturbed by uncorrelated signals, as is standard practice [1]. Such a correlation reduces identifiability.

In principal component analysis (PCA), the maximum amount of information is extracted from a data matrix X into a number of components less than the number of variables in X. The component data vectors (score vectors) are norm-bounded linear combinations of the X columns with maximum sample variance and no sample correlation between component vectors (they are orthogonal). In line with PCA, the aim of the input design proposed in this contribution is to maximize the information content of the outputs by producing uncorrelated outputs with sample variances at some maximum desired level.

The author has previously presented a model-based input design method to obtain uncorrelated outputs with specified variances [2–4]. In this contribution, a purely data-based input design method is proposed. Naturally, this is preferable from a practical point of view. The data are obtained from one or several preliminary experiments with the system to be identified. In the case of one experiment, it can be a standard MIMO experiment with uncorrelated inputs, but better data for the design is usually obtained by performing experiments with one input at a time.

Let the MIMO system to be identified have n inputs and n outputs with numerical values $u(k)$ and $y(k)$, respectively, at sampling instant k. The dynamics of the system can be described by the model

$$y(k) = G(\mathrm{q})u(k),$$

where $G(\mathrm{q})$ is a matrix of pulse transfer operators defined through the shift operator q. The input design does not require knowledge of this model and it is not required that a model of this form is identified; it is mainly introduced to facilitate the description below.

The input design is based on the use of an n-dimensional perturbation signal $\xi(k)$. Usually, this signal is a random binary sequence (RBS), a pseudo-random binary sequence (PRBS), or a multi-sinusoidal signal (MSS). The individual signals $\xi_i(k)$, $i = 1, \dots, n$, should preferably be uncorrelated with one another as in a standard identification experiment. The input design is done by deriving a linear combination

$$u(k) = T\xi(k)$$

that will produce uncorrelated outputs $y(k)$ with desired variances. This design is based on data obtained from the previously mentioned experiment(s).

For an $n \times n$ system, the output covariance matrix is defined by $n(n+1)/2$ parameters. This means that the same number of independent elements of T is sufficient to determine the output covariance matrix, which in the case of uncorrelated outputs with variance 1 is the identity matrix. This can be achieved by a triangular or symmetric/skew-symmetric T matrix (including row and column permutations), for example. If a full T matrix is used, some additional property besides output correlation can be optimized. It is possible, for example, to minimize input or output peak values, or the input crest factor. Such options are illustrated by the use of an ill-conditioned distillation column model.

References

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