An All-Interaction-Matrix Approach to Linear and Bilinear System Identification

F. Vicario[1], M. Q. Phan[2], R. W. Longman[1,3], and R. Betti[3]

Abstract: This paper illustrates the interaction matrix technique and how, solely by the use of interaction matrices, several algorithms can be derived for the identification of linear and bilinear discrete-time state-space models from measured input-output data.

The concept of interaction matrix was originally formulated by Minh Q. Phan in the context of linear system identification of lightly-damped large flexible space structures. The dynamics of such structures can be described by the system Markov parameters. The interaction matrix provides a mechanism to compress an infinite sequence of system Markov parameters into a finite sequence that can be easily identified from input-output measurements. Subsequent development revealed that in the presence of noise in the data the interaction matrix could be interpreted as a Kalman filter gain. This finding led to the core equation of the Observer/Kalman filter Identification (OKID) approach and the development of the well-known OKID/ERA algorithm (OKID followed by Eigensystem Realization Algorithm). Additionally, interaction matrices have found applications in other areas such as bilinear system identification, model predictive control and iterative learning control.

This paper generalizes the interaction matrix technique in linear and bilinear system identification, exploiting interaction matrices to express the system state as a function solely of input-output data. These relationships, referred to as Input-Output-to-State Representations (IOSRs), are then used to derive algorithms for the identification of state-space models from noise-free input-output data, in particular the Deterministic Intersection and the Superspace algorithms. The former is based on the intersection of the row spaces of two data matrices constructed from causal and anticausal IOSRs, whereas the latter exploits a single IOSR to solve by least-squares method the state-space model equations directly for the model matrices. Following recent development in OKID, the above mentioned algorithms are also shown to be an alternative to ERA for the identification of the Kalman filter underlying OKID, for an all-interaction matrix approach to system identification even in the presence of process and measurement noise.

---

[1] Department of Mechanical Engineering
Columbia University, New York, NY 10027, USA
fv2157@columbia.edu, rwl4@columbia.edu

[2] Thayer School of Engineering
Dartmouth College, Hanover, NH 03755, USA
minh.q.phan@dartmouth.edu

[3] Department of Civil Engineering and Engineering Mechanics
Columbia University, New York, NY 10027, USA
rwl4@columbia.edu, rb68@columbia.edu