Spring 2020

CEE 629. System Identification

Instructor: Henri P. Gavin, 162 Hudson Annex, `Henri.Gavin@Duke.edu`

Class: Tu, Th, 11:45 - 1:00, CIEMAS 2409 (B)

Office Hours: t.b.d.

References:
- Chen, C.T., *Linear System Theory and Design*, 3rd ed., Oxford, 1999.
- Katayama, Tohru, *Subspace Methods for System Identification,* Springer, 2005.
- Van Overschee, Peter, and De Moore, Bart, *Subspace Identification for Linear Systems,* Kluwer, 1996.
- Juang, Jer-Nan, *Applied System Identification,* Prentice Hall, 1994.

Course Website: http://www.duke.edu/~hpgavin/SystemID/

Academic Integrity: *The Duke Community Standard* applies.

Grading: Homework(6) 50%; Project(1) 50%

Overview

System Identification is the process of relating the reality of measured data sets to the idealization of mathematical models. Identified models reveal the phenomenae and processes at work within actual systems and are useful in predicting system responses, designing system controllers, and quantifying uncertainties. Models considered in this course take the form of systems of ordinary differential equations. Recent advances in subspace methods for system identification provide a means to estimate high dimensional linear state-space realizations from sparse noisy measurements of input-output data (or output-only data) via a QR decomposition and an SVD decomposition of Hankel matrices of the data. Subspace methods are direct in the sense that they do not require an initial guess of a canonical model, or the model order, or a convergent iterative algorithm. The course will start with a review of some tools of numerical linear algebra, the formulation of ordinary and total least squares problems, and projections of linear vector spaces. These tools will then be applied to the estimation of state-space models via eigensystem realization and subspace ID.

Week : Topic

1 : Nonlinear Constrained Optimization, in general
Least squares and Levenberg-Marquardt; Nelder-Mead; KKT and Sequential Quadratic Programming; error propagation. ℓ_2 regularization and ℓ_1 regularization as a QP, Prony series.

2-3 : Matrix Decompositions
linear vector spaces, Householder and QR decomposition; singular value decomposition; truncation.

4-5 : Total Least Squares, Singular Spectrum Analysis
Eckart-Young thm, total least squares, and structured total least squares; orthogonal and oblique projections; filtering via rank-reduced Hankel matrices;

6-8 : Discrete-time state-space models
impulse response, convolution and frequency response; Kalman filter; controllability, observability, and gramians; Lyapunov equations, balanced realizations, and model reduction. MIMO Wiener filters and recursive least squares.

8-9 : Eigensystem Realization with Kalman Observer
Hankel matrices of Markov parameters; system and observer Markov parameters; the eigensystem realization algorithm; OKID, modal analysis, Hankel singular values and stochastic OKID.

10-12 : Subspace Identification
input, output, and state matrices; persistent disturbance and subspace intersections; orthogonal and oblique projections via LQ decomposition; deterministic subspace id (N4SID,MOESP); stochastic subspace id (CVA,CCA).

13 : Applications / Projects
possibly including *real* measurements from laboratory or field experiments.