TWO-DAY TUTORIAL WORKSHOP - SYLLABUS
(AND EITHER DAY OFFERED AS A ONE-DAY WORKSHOP)

AMERICAN CONTROL CONFERENCE, 2007

RECENT ADVANCES IN SUBSPACE SYSTEM IDENTIFICATION: LINEAR, NONLINEAR, CLOSED-LOOP, AND OPTIMAL WITH APPLICATIONS

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This workshop presents a first principles development of subspace system identification (ID) using a fundamental statistical approach. This includes basic concepts of reduced rank modeling of ill-conditioned data to obtain the most appropriate statistical model structure and order using optimal maximum likelihood methods. These principles are first applied to the well developed subspace ID of linear dynamic models; and using recent results, it is extended to closed-loop linear systems and then general nonlinear closed-loop systems.

The fundamental statistical approach gives expressions of the multistep likelihood function for subspace identification of both linear and nonlinear systems. This leads to direct estimation of the parameters using singular value decomposition type methods that avoid iterative nonlinear parameter optimization. The result is statistically optimal maximum likelihood parameter estimates and likelihood ratio tests of hypotheses. The parameter estimates have optimal Cramer-Rao lower bound accuracy, and the likelihood ratio hypothesis tests on model structure, model change, and process faults produce optimal decisions. Comparisons are made between various system identification methods including subspace, prediction error, and maximum likelihood.

The extension to general nonlinear systems determines optimal nonlinear functions of the past and future using the theory of maximal correlation. This gives the nonlinear canonical variate analysis. New results show that to avoid redundancy and obtain gaussian variables, it is necessary to determine independent canonical variables that are then used in the likelihood function evaluation. This gives a complete likelihood theory for general nonlinear stochastic system with continuous dynamics and possibly feedback.

These new results greatly extend the possible applications of subspace ID to closed-loop linear and nonlinear systems for monitoring, fault detection, control design, and robust and adaptive control. The precise statistical theory gives tight bounds on the model accuracy that can be used in robust control analysis and design. Also precise distribution theory is available for tests of hypotheses on model structure, process changes and faults. Potential applications include system fault detection for control reconfiguration, autonomous system monitoring and learning control, and highly nonlinear processes in emerging fields such as bioinformatics and nano technology. Applications are discussed to monitoring and fault detection in closed-loop chemical processes, identification of vibrating structures under feedback, online adaptive control of aircraft wing flutter, and identification of the chaotic Lorenz attractor.

The intended audience includes practitioners who are primarily interested in applying system identification techniques, engineers who desire an introduction to the concepts of subspace system identification, and faculty members and graduate students who wish to pursue research into some of the more advanced topics. Attendees may register for either day as a 1-Day Workshop, or both days as a 2-Day Workshop (the first day has been previously attended hundreds of attendees).

SCHEDULE - DAY ONE - LINEAR SYSTEMS WITH FEEDBACK

8:30-9:15 OVERVIEW OF SUBSPACE SYSTEM IDENTIFICATION
- Approaches and Algorithms
- Positivity, Stability, Accuracy, Computation

9:15-10:00 RANK OF A STOCHASTIC DYNAMIC SYSTEM
- Statistical Rank - Canonical Variate Analysis (CVA)
- Rank as Minimal State Order

Break

10:30-11:15 SUBSPACE MAXIMUM LIKELIHOOD ESTIMATION
- Multistep Likelihood Function
- State Space Regression Equations

11:15-12:00 STATISTICAL MODEL ORDER/STRUCTURE SELECTION
- Kullback Information and Akaike Information
- Accuracy of Estimated Model

Lunch Break

1:00-2:00 COMPARISON OF ALTERNATIVE SYSTEM IDENTIFICATION APPROACHES
- Model Structure Selection and Parameter Estimation
- Computational Issues and Software

2:00-2:45 OPTIMAL IDENTIFICATION OF I/O AND CLOSED-LOOP SYSTEMS
- Removing Effect of Future Inputs
- Model Nesting and Sufficient Statistics

3:15-4:00 PROCESS MONITORING USING CVA
- Low Rank Process Characterization by CVA
- Testing Hypotheses of Process Change

Break

4:00-4:45 PROCESS MONITORING APPLICATIONS
- Tennessee Eastman Challenge Problem
- Comparison with SPC and PCA Methods

4:45-5:30 IDENTIFICATION AND CONTROL APPLICATIONS
- Vibrating Structures
- On-line Adaptive Control of Aircraft Wing Flutter

SCHEDULE - DAY TWO - NONLINEAR SYSTEMS

8:30-9:15 OVERVIEW OF NONLINEAR SYSTEM IDENTIFICATION METHODS
- Hammerstein and Wiener Systems
- Nonlinear State Space Models

9:15-10:00 NONLINEAR CANONICAL VARIATE ANALYSIS
- Nonlinear Functions of Past and Future
- Multivariate Reduction by Maximal Correlation

Break

10:30-11:15 MAXIMAL CORRELATION AND PROJECTION

- Definition and Properties
- Outline of Function Space Concepts

11:15-12:00 MINIMAL STATE RANK AND INDEPENDENT CVA

- Redundancy Problem with CVA
- Optimal Transformations to Gaussian Variables

Lunch Break

1:00-2:00 LIKELIHOOD FUNCTION FOR NONLINEAR SYSTEMS

- Multistep Likelihood
- Optimality of Independent CVA

2:00-2:45 OPTIMALITY IN CLOSED LOOP

- Remove Future Inputs with NARX
- Model Nesting and Nonlinear Regression

3:15-4:00 COMPARISON WITH OTHER METHODS

- Neural Networks, Statistical Learning
- Support Vector Machines

Break

4:00-4:45 COMPUTATIONAL METHODS

- Alternating Conditional Expectation (ACE)
- Kernel based Computation

4:45-5:30 LORENTZ ATTRACTOR IDENTIFICATION

- Nonlinear Dynamics and Noise
- Computation and Identification Accuracy