Spring 2017

CE 599: System Identification

Sonny Astani Department of Civil and Environmental Engineering
University of Southern California

The need to infer models of an unknown system from observed input and output data is ubiquitous in engineering, with applications spanning multiple disciplines. Invariably, one has to assume some structure of the model to make meaningful inferences. While many students are exposed to the topic of regression in their undergraduate courses, its applicability is severely limited.
This is a special topics PhD level course dealing with the problem of estimating or building *dynamical* models of systems based on observed time series data. While the majority of the course focuses on techniques for linear time invariant systems, a considerable amount of time is also dedicated to nonlinear and time varying systems. The course content is heavily focused on techniques and algorithms, supplemented with periodic Matlab exercises (homework and in-class) using the System Identification Toolbox. A few lectures are also devoted to convergence analysis of some of the proposed techniques to help students gain a deeper understanding of the proposed techniques. A final class project will help students to apply the system identification techniques learned in this course to a topic of their choice.

Course Instructor

Ketan Savla, KAP 254A, 213 740 0670, ksavla@usc.edu.
Office hours: TBD

Class location, hours, and website

Wednesdays 3:30 pm – 6:10 pm, location KAP 138
The class will use the blackboard website at USC, https://blackboard.usc.edu/, as the primary medium for distribution of course material and announcements.

Prerequisites

- Linear control systems (e.g., EE 482, or AME 451);
- Basic probability (e.g., CE 408, EE 364, or MATH 407);
- Exposure to basic optimization (e.g., ISE 330)

Grading

- 35% Homeworks
  There will be a total of six homeworks in this course.
- 25% Take home midterm exam
- 40% Course project

The course material will be derived primarily from the following two books. Note that [2] can be accessed online through USC libraries.

Required Textbooks

[1] Ljung Lennart. *System identification: theory for the user*. Information and System Sciences Series. Prentice Hall PTR, USA, 2nd edition, 1999.

[2] Stephen A Billings. *Nonlinear system identification: NARMAX methods in the time, frequency, and spatio-temporal domains*. John Wiley & Sons, 2013. 2

Class project

The purpose of the class project is to encourage students to explore material related to but outside the material covered in lectures, and possibly relate it to their own research. It is expected that the students will work individually on their projects.

Students will individually select a topic, possibly with the help of the instructor. Students are then expected to do literature review, perform theoretical or numerical research, write a report and present their results to the class. It is expected that the final output of the project will be suitable for a technical report.

Important dates for the class project

Project proposal due: February 22, 2017 (via email to the instructor)
In-class project presentation: April 26, 2017
Final report due: May 10, 2017 (via email to the instructor)

Project proposal: One page document, minimum of 10 pt, single spaced, single column, containing:

1. project topic,
2. name of the student,
3. references to the material that the student plans to cover, and
4. short description of the goals of the project.

Final report: A maximum of 8 page document, minimum of 10 pt, single spaced, single column, containing:

1. project topic,
2. name of the student,
3. review of literature,
4. final results and conclusion.

In-class presentation: A total of 20 min consisting of a 15-min presentation (maximum of 15 slides), followed by a 5 min Q & A session with the instructor and the class.

Tentative Course Schedule

The schedule of the course is shown in Table 1. The list of topics to be covered during each class are listed below:

1. Introduction and LTI Models: FIR, MA, ARMA, ARX, ARMAX, Models, Linear Least Squares Method, Signal Spectra, Intro to Matlab System Identification Toolbox
2. Nonparametric Methods: Frequency response analysis, Fourier analysis, Spectral analysis
3. Parametric Methods I: Linear regression, Subspace algorithm
4. Parametric Methods II: Correlation approach, Maximum likelihood estimation and its asymptotic properties
5. Parametric Methods III and Convergence Analysis I: Instrumental-variable methods, Prediction-error approach
6. Convergence Analysis II: Consistency, Asymptotic variance (time and frequency domain)
7. Numerical Techniques for Parameter Estimation: Iterative search, Gradient computation, Subspace methods
8. Experiment Design: Persistence of excitation, Identifiability, Closed loop identification
9. Hands-on Case Studies: Demonstration of the System Identification toolbox
10. Nonlinear Models: Linearization, Wiener and Hammerstein models, Function expansions and basis functions
11. Nonlinear System Identification I: Volterra series representation, Generalized frequency response functions and its estimation
12. Nonlinear System Identification II: Neural networks, Wavelets, Fuzzy models
13. System Identification for Time-Varying Systems: Kalman filter algorithm, Recursive least squares approach, Multi-wavelet approach

$*$: Homework # 3 will be due on Friday, March 3 2017.
$*$: Homework # 4 will be due on Friday, March 24 2017.

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* `https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions`. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, `http://policy.usc.edu/scientific-misconduct`.
Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* `http://equity.usc.edu` or to the *Department of Public Safety* `http://adminopsnet.usc.edu/department/department-public-safety`. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. The *Center for Women and Men* `http://www.usc.edu/student-affairs/cwm/` provides 24/7 confidential support, and the sexual assault resource center webpage `http://sarc.usc.edu` describes reporting options and other resources.

Date	Topics	HW # out	HW # due
11 Jan	Introduction and LTI models		
18 Jan	Nonparametric Methods	1	
25 Jan	Parametric Methods I		
1 Feb	Parametric Methods II	2	1
8 Feb	Parametric Methods III & Convergence Analysis I		
15 Feb	Convergence Analysis II	3	2
22 Feb	Numerical Techniques for Parameter Estimation		
1 Mar	Experiment Design	4	3*
8 March	Mid Term Exam		
15 March	Spring Recess - no class		
22 March	Hands-on Case Studies	5	4*
29 March	Nonlinear Models		
5 April	Nonlinear System Identification I	6	5
12 April	Nonlinear System Identification II		
19 April	System Identification for Time-Varying Systems		6
26 April	Project Presentations		

Table 1: Tentative Course Schedule

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* `http://dornsife.usc.edu/ali`, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* `http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html` provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* `http://emergency.usc.edu` will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.