# Fall 2014

**ME 597: System Identification**

**INSTRUCTOR: KARTIK B. ARIYUR**

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Office Hours: **Friday, 1—4pm**

**COURSE TEXT:** There is no text book for the course. Reading material will be posted on the course blackboard site periodically. The site is:

[https://mycourses.purdue.edu](https://mycourses.purdue.edu/)

Lecture handouts will be posted to the course website before each lecture.

## REFERENCES:

[1] *System Identification: Theory for the User,* L. Ljung, Prentice-Hall, 2nd Ed., 1999.

[2] *Identification of Dynamic Systems*, R. Isermann and M. Munchoff, Springer, 2011 (Available from Purdue Library online).

Other reference materials will be provided via Purdue Blackboard

**PREREQUISITE:** Random Variables/Signal Processing (ME579)/Digital Control (ME578), industrial experience or the consent of the instructor.

**OBJECTIVES:** This course connects mathematical models to experimental data. It is intended to facilitate the students to gain:

* Familiarity with the method of least squares and the numerical methods used to implement it.
* An understanding of real analysis and the algebra of random variables adequate for connecting the real world of experimental data to the abstract world of mathematical models.
* Familiarity with various empirical and semi empirical model structures that can be identified from data.
* The ability to extract physical parameters from experimental data, whether the physical system is lumped or distributed; discrete or continuous.
* The ability to determine if the parameters extracted from data have any predictive or extrapolative power.
* An understanding of implementation issues—such as designing experiments, selecting model orders, noise levels, and preprocessing data.

In the main, this course seeks to simulate the work environment of the modern engineer or scientist. It aims at familiarity with algorithmic tools, their analytical and numerical

foundations, and the ability to obtain relevant information to solve practical problems.

## GRADING POLICY:

**COURSE PROJECT: 50% IN-CLASS QUIZZES: 50%**

Bonus questions will be posted online on Blackboard periodically—correct answers (there can be several) will receive 2 points each. Final grading will be cluster based.

**You must receive a passing grade on the project to pass the course. There is NO homework, and your project is the main measure of your efforts.**

**PROJECT POLICY:**

Project reporting has to be done each week. **Project updates have to be submitted via Blackboard by the following Sundays, 11:59pm EST (September 7, 14, 21, 28; October**

**12, 26; November 9, 23, 30; December 7)** . This includes your work of the previous week and your MATLAB/SIMULINK code (clearly documented). *No late submissions will receive*

*points*. Since projects are an integral part of the course content, they are to be an individual effort. However, study group discussion, acquiring information and code from the web and

library, MATLAB/SIMULINK code sharing/reuse, and cross-checking each other’s work, are strongly encouraged. Project updates must be uploaded in the format specified, in pdf,

and must NOT add more than 2 pages to the overall document. The final document must occupy 15 pages or less. You can trim/modify prior sections when you update the report on

each submission.

Each project update will be worth 50 points. 10 points will be deducted for each of

consistency, correctness, formatting/typographic/referencing, coding/code formatting, and spelling/grammar. There will be 10-point bonuses for exceptional accomplishments from

time to time. Project updates will consist **APPROXIMATELY** in the following steps:

1. Problem background, motivation and formulation with references
2. Model (=dynamics+uncertainty) to be identified from experimental data
3. Initial experiment design/data collection/preprocessing
4. Parameter estimation
5. Checking for convergence and consistency of estimates and distributions
6. Computational issues
7. Optimal parameterization
8. Model (in)validation
9. Real-time and closed loop state and parameter estimation
10. Experiment design and preprocessing issues

**QUIZ POLICY:**

Quizzes will be on **Mondays (September 8, 15, 22, 29; October 6, 20, 27; November 3,**

**10, 17, 24; December 1)** and you will have 1 hour between accessing the quiz and submitting your solution scan on Blackboard along with a summary of the course up to that point (a cribsheet of all formulae/theorems you use). Grading will be based on the correct answer and the correct method. Each quiz will be worth 50 points and will consist in a single question—the best 10 scores will be considered for your grade. You will receive **ZERO** points for incorrect answers or for correct answers with incorrect methods (if that happens). The questions may have multiple correct answers. The quiz will be open notes/books—you can use the internet as well—but collaboration is forbidden and the usual penalties accrue on detection. Discussion of your summary sheet (crib sheet) with classmates however is strongly encouraged.

**BONUS QUESTION POLICY:**

All correct answers to bonus questions will get credit. In case several of you give the

same answer, the first person to do so on the blog will get credit.

***Grading will be performed in the week of the project update submission or quiz and posted on BLACKBOARD, so you can check on your performance regularly.***

## COMPUTER USAGE:

Course communication—announcements, lecture notes, scores and averages—will be

through the course web site at [https://mycourses.purdue.edu.](https://mycourses.purdue.edu/) When you login with your Purdue Career account access you should be able to access the ME597 site. You should check the web site at least once a day. You will be expected to use MATLAB/SIMULINK for the course project. It is strongly advised that you go through a self-paced MATLAB tutorial such as the one at <http://www.engin.umich.edu/class/ctms/>if you are not comfortable with MATLAB. It is a bit out-dated but the fundamentals are the same.

## TENTATIVE COURSE OUTLINE

1. **Introduction and Least Squares Methods 1 week**

Connecting Models and Data Linear regression



Nonlinear regression

Distributions of parameter estimates

## Models and Identifiability 3 weeks

Analysis and random variables Difference equation (DE) models



Mapping ODE/PDE models to discrete DE models Identifiability

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| --- | --- | --- |
| **3.** | **Implementation Issues** | **1 week** |
| 4. | **Parameter Estimation Methods** | **2 weeks** |

Batch methods Recursive methods



## Convergence and Consistency—Batch methods 2 weeks

Statistical framework—least squares and maximum likelihood Prediction error and correlation approaches



Fitting transfer function models to frequency response data

## Distributions of parameter estimates 1 week

Batch methods Recursive methods



## Computational Issues 1 week

Solving least squares problems Iterative methods



Estimating state space models

## ‘Optimal’ Identification Criteria 1 week

Robustness Minimizing variance



## Model (In)Validation 1 week

Selection of model structure Selection of model order



## Real-time and Closed loop System ID 1 week