Fall 2014

Posted March 2014

AERO 540 (ME 540) [Forbes]

AERO 548 (Astrodynamics) [Kolmanovsky]

AE566 (Data Analysis and System Identification) [Bernstein]

EECS 418 (Power Electronics)[Hofmann]

EECS 460 [Ozay]

EECS 461 [Freudenberg]

EECS 498 [Revzen](Hands-on Robotics) (special topics on EE Web page)

EECS 501 [Teneketzis]

EECS 560 (AERO 550) (ME 564) [Gillespie]

EECS 566 [Lafortune](Discrete Event Systems)

EECS 598 [Mathieu] Power System Dynamics and Control

EECS 662 [Meerkov] Advanced Nonlinear Control {Note: Many of the topics covered by Prof. Meerkov do not require 562, and he will review required facts from 562 before using them.}

ME 548 [Orosz] Applied Nonlinear Dynamics (see flyer)

ME 560 [Stein]

ME 564 (AERO 550)(EECS 560) [Gillespie]

ME 569 [Stefanopoulou] Advanced Powertrain Systems

MATH 658 [Bloch] (Nonlinear Dynamics and Geometic Mechanics)(Tu-Th 10:00 to 11:30)

NA 531 [Sun] Adaptive Control (Tu-Th 4:30 to 6:00 PM)

ROB 501 [Grizzle] Mathematics for Robotics (Details will be posted when available)

PhD-level optimization courses

IOE 610 - M/W 9:00-10:30am - 1680 IOE (Linear Programming; instructor TBD)

IOE 611 - T/TH 12:00-1:30pm - 1690 Beyster (Convex Optimization (unofficial title), Epelman)

IOE 691 - M/W 12:00-1:30pm - 3427 EECS (Stochastic and Robust Optimization, Shen with guest appearances by Epelman)

IOE 611/MATH 663: Nonlinear Programming, Winter 2013

(Updated 01/11/13) This is a preliminary version of the syllabus. The final version will be published a few weeks into the class.

Lectures: Mondays and Wednesdays, 10:30–noon, 1690 Beyster.

Teaching Staff:
Instructor: Prof. Marina A. Epelman, mepelman@umich.edu
Office: 2845 IOE
Office hours: see course site on CTools for current schedule.

Required background: Exposure to numerical computing, optimization, and its application fields is helpful but not required. IOE 510/Math 561 is a formal recommended prerequisite; this or another mathematical optimization course (e.g., IOE 511 or IOE 519) would be helpful, but not necessary. To be able to keep up with the course, the students must have good knowledge of linear algebra and mathematical analysis/advanced calculus, as well as willingness to program in Matlab (prior knowledge is not necessary, but I expect you to learn via self-study in the early parts of the semester).

Catalog description: Modeling, theorems of alternatives, convex sets, convex and generalized convex functions, convex inequality systems, necessary and sufficient optimality conditions, duality theory, algorithms for quadratic programming, linear complementary problems, and fixed point computing. Methods of direct search, Newton and Quasi-Newton, gradient projection, feasible direction, reduced gradient; solution methods for nonlinear equations.

Informal description: In this offering of the course we will focus on convex optimization. As this is an advanced course, the topics covered and their depth will sometimes be determined as we go. The broad areas we will cover (not necessarily in the specified order) in various depths are:

- Convex sets and convex functions
- Convex optimization problems, including linear, quadratic, semidefinite, and other special problems
- Applications of convex optimization
- Duality and optimality conditions
- Algorithms for unconstrained and constrained convex optimization, including interior point methods and, time permitting, first order methods.

Readings and reference books:

The primary source of reading will be the text *Convex Optimization* by Stephen Boyd and Lieven Vandenberghe. Campus book stores with stock some copies, but new and used copies can be obtained from various online retailers at competitive prices. Beware that, although the book is still in the first edition, there has been several printings, each correcting some errors and typos — keep track of these through the errata file on the book website. The .pdf file of the book is also available on the web at

`http://www.stanford.edu/~boyd/cvxbook/`

You are welcome to download this file and use it as a reference (e.g., it's helpful to be able to search the text), however the book is over 700 pages long, and therefore, you should not plan on printing it out. In particular, the IOE department explicitly disallowed using IOE printers to print out significant portions of the book!

If time permits, we will also work through several journal articles, which will be distributed on CTools.

Additional recommended reference books:

- *Nonlinear Programming: Theory and Algorithms* by M. Bazaraa, H. Sherali, and C. Shetty
- *Lectures on Modern Convex Optimization* by A. Ben-Tal and A. Nemirovski
- *Introduction to Linear Programming* by D. Bertsimas and J. Tsitsiklis
- *Nonlinear Programming* by D. Bertsekas
- *Convex Analysis and Optimization* by D. Bertsekas
- *Introductory Lectures on Convex Optimization* by Y. Nesterov
- *Numerical Optimization* by J. Nocedal and S. Wright
- *Nonlinear Optimization* by A. Ruszczynski

Grading Homework assignments will be posted roughly weekly, however, they will not be graded. Homework solutions will be posted a week after the assignment. Your grade will be determined based on four take-home exams (the first two are worth 20% each, and the third and forth are worth 30% each of the final grade).

You are required to type rather than hand-write exam submissions. In addition to making the grading process faster, typing your answers allows you to edit your notation, explanations and derivations for correctness, clarity and ease of understanding, which often leads to higher scores. I recommend that you learn the basics of LaTeX typesetting system, if you haven't already, and use it to prepare your solutions. A sample file, and a file of commands defined to properly typeset mathematical notation items used in the book will be made available with the first homework.

Although the homework assignments will not be graded, it is imperative that you solve homework problems completely (i.e., not just figure out a plausible solution approach, but provide a complete and rigorous solution), including writing (ideally, typing) up those solutions, and doing all the coding work that is requested in the homework. The material we will be covering, and problems we will be solving, in this class require a lot of deliberate practice to master, and if you don't put the effort in, you will not be able to successfully complete the exams in the time allotted. I will hold weekly office hours, during which you are encouraged to discuss the lectures, as well as approaches and ideas for solving homework problems, as well as ask followup questions once homework solutions have been posted.

Independent work policies As references during exams you can use the course textbook and your notes, including distributed homework solutions, only. (Of course, you are allowed to cite "general knowledge" facts that are not explicitly discussed in the book, such as, for example, facts from calculus, analysis, probability theory, linear algebra, etc. The spirit of the above restriction is that you shouldn't search other textbooks, or journals, or the web, or solution manuals, for solutions or hints for approaches to exam problems.) You are not allowed to discuss the exam with anyone other than the instructor until the end of the takehome period.

Honor code All students are expected to be familiar with the Engineering Honor Code, and are bound by its requirements on all homework and examinations.

Visitors are welcome in the course, assuming there is sufficient space. Registered students always have seating priority. If possible, please register for the course as a visitor. To receive visitor credit, you must regularly attend lectures, do the assigned reading, and participate in the classroom discussion.

Mathematics 658

Nonlinear Dynamics and Geometic Mechanics

Instructor: Anthony M. Bloch.

Office: 4842 East Hall. Tel: 647-4980 Email: abloch@umich.edu

Webpage: http://www.math.lsa.umich.edu/˜ abloch

Fall Term, 2014, TTh 10-11.30

This course will discuss geometric aspects of the modern theory of ordinary differential equations and dynamical systems, with applications to various mechanical and physical systems. Topics will include: the qualitative theory of ODE's on manifolds, symplectic and Poisson geometry, nonlinear stability theory, Lagrangian and Hamiltonian mechanics, integrable systems, reduction and symmetries, mechanical systems with constraints and controls, and optimal control.

Recommended texts: The course will be drawn from several sources. The main text will be A. Bloch, Nonholonomic Mechanics and Control, Springer Verlag. Other books will be referenced as well as the primary mathematical literature.

Prerequisite: Some background in differential equations and some mathematical sophistication.

Grading: The course grade will be based mainly on completion of problem sets and general class participation.

SYLLABUS
IOE 691: Stochastic and Robust Optimization, Winter 2013

Instructors: Siqian Shen (siqian@umich.edu) and Marina Epelman (mepelman@umich.edu)
Lecture: TuTh 9:00AM–0:30AM, 3433 EECS

Textbook:

- *Stochastic Programming:*
  - John Birge and Francois Louveaux. (2011) *Introduction to Stochastic Programming.* 2nd Edition. Springer. (**Required**)
  - Alexander Shapiro, Darinka Dentcheva, Andrzej Ruszczynski. (2009) *Lectures on Stochastic Programming: Modeling and Theory.* SIAM-Society for Industrial and Applied Mathematics. (**Optional; free electronic pdf is available on the authors' website.**)
- *Robust Optimization:*
  - Aharon Ben-Tal, Laurent El Ghaoui, Arkadi Nemirovski (2009) *Robust Optimization.* Princeton University Press. (**Available electronically through UM Libraries.**)

Prerequisites: IOE 610 and IOE 515.

Course Description:

- The course is roughly separated into three parts: stochastic programming (2 months), robust optimization (1 month), special topics (3 weeks).
- Target audiences are PhD students interested in the **theory** of stochastic/robust optimization.

Topics:

- Stochastic Programming (SP) (Instructor: Siqian Shen):
  - ***Fundamentals:*** Convex analysis, probability theory (random variables, distributions, etc.).
  - ***Two-stage Stochastic Optimization:*** Recourse problems, Benders decomposition, Lagrangian relaxation, the L-shaped method and its variants, stochastic integer programming, generalized Benders cuts, Laporte-Louveaux (LL) inequalities.
  - ***Multi-stage Stochastic Optimization:*** Nested L-shape method (Benders cuts), scenario trees.
  - ***Chance-Constrained Programming:*** Formulations and reformulations, deterministic equivalence, joint chance constraints, p-efficient points, Dantzig-Wolf decomposition, bound and inequalities.
  - ***Approximations:*** Monte-Carlo sampling, the sample average approximation (SAA) method, Conditional Value-at-Risk (CVaR), the value of information, the value of stochastic solution.

- ◇ Robust Optimization (RO) (Instructor: Marina Epelman):
  - ***Fundamentals:*** Tractable (convex) optimization problems.
  - ***Robust counterparts of uncertain LPs:*** Introduction and examples, duality in robust optimization, choice of uncertainty sets, globalized robust counterparts (time permitting).
  - ***Multi-stage RO:*** Adjustable robust counterparts of uncertain LPs; affinity adjustable robust counterparts; robust dynamic programming (time permitting).
  - ***Robust discrete optimization:*** Single- and multi-stage examples.
  - ***Solution methods:*** Back to Benders.
  - ***Minimax stochastic programming*** (time permitting).
- ◇ Special Topics (Instructor: Siqian Shen):
  - Optimization under ambiguity.
  - Data-driven problems and distributionally robust modeling.
  - Relationship between SP and RO.

Workload:

- ◇ Several homework assignments which will focus on both rigorous proofs of theorems, as well as analysis and implementations of algorithms.
- ◇ A project that will describe a problem, and have each student developing models and algorithms, as well as implementing the code in optimization solvers (e.g., CPLEX) for solving the problem.
- ◇ Exam 1 and Exam 2 (most likely take-home) respectively after the first two parts of the course (time TBD).
- ◇ For homeworks and project (and exams, if they are take-home), we require all submitted work typed in LaTeX.

Final Grades: Homework 25% + Exam1 25% + Exam2 25% + Project 25%.

Independent work policies: You are allowed (indeed, encouraged) to discuss homework problems with other students. However, the work submitted by you should be your own writing/typing, and if programming is involved, you will also be responsible for the correctness of the code used and reported computational results. Copying or rephrasing of another person's written answers or code is unacceptable. If you rely on any sources other than the lecture material, recommended textbooks or reading materials distributed to the entire class via CTools, you should give appropriate credit and reference the source, just as you would in an academic paper. Exam policies will be announced separately.

Honor code: All students are expected to be familiar with the Engineering Honor Code, and are bound by its requirements on all homework and examinations.

Visitors are welcome in the course, assuming there is sufficient space. Registered students always have seating priority. We encourage you to register to audit the course. You would not be required to submit homeworks and exams, but to receive "audit" credit, you must regularly attend lectures, read assigned materials, and participate in the classroom discussion.

University of Michigan Disability Statement: The University of Michigan is committed to providing equal opportunity for participation in all programs, services and activities. Request for accommodations by persons with disabilities may be made by contacting the Services for Students with Disabilities (SSD) Office located at G 664 Haven Hall. The SSD phone number is 734-763-3000. Once your eligibility for an accommodation has been determined you will be issued a verified individual services accommodation (VISA) form. Please present this form to me at the beginning of the semester to allow processing time for special accommodation for the lectures, projects, tests, and exams.

Important Links:

- ◇ The Engineering Honor Council: `http://www.engin.umich.edu/students/honorcode/`
- ◇ Honor Code: `http://www.engin.umich.edu/students/honorcode/brochure.pdf`
- ◇ UM Counseling and Psychological Services: `http://www.umich.edu/~caps/services.html`
- ◇ Sexual Assault Prevention and Awareness Center: `http://www.umich.edu/~sapac/`
- ◇ UM Academic Calendar: `http://ro.umich.edu/calendar/fa11deadlines.php`

Data Analysis and System Identification

AE566, Fall 2014

Course Objective: System identification is data-based modeling. In this course students will learn techniques for using data to construct and refine linear and nonlinear models that can be used for physical insight, health diagnostics, prediction, and control. This course is practice-oriented with emphasis on applying methods rather than developing theory (although theory will be presented in lectures), and will cover a broad range of algorithms, which students will learn to use and apply to data sets.

Audience Students from all COE departments and areas outside COE are encouraged to take advantage of this course to develop techniques for use in their research. This course is offered approximately once every 3 or 4 years.

Prerequisites This 3-credit course is suitable for graduate students in any area of engineering or science. Although the course has no specific prerequisites, facility with Matlab is assumed and some knowledge of linear systems will be helpful. No textbook is required.

Instructor: Prof. D. S. Bernstein, 3020 FXB, dsbaero@umich.edu

Meets: Wednesdays and Fridays 8:30-10:00, FXB 1008

Grading: Biweekly graded homework 50%, Project 50%, No tests

Course Content Lectures will cover linear and nonlinear system ID concepts and techniques in the time and frequency domain. Time-domain batch and recursive least squares fits of time series and state space models, input-output and output-only models, stochastic models (noise, correlation, bias, consistency, persistency), frequency domain analysis and ID (FFT data fits), inverse FFT and Markov parameters for state space realization, parameter estimation methods (optimization techniques, extended Kalman filter), nonlinear model structures and ID techniques (block-structured models [Hammerstein/Wiener, nonlinear feedback], radial basis functions, NARMAX, bilinear, LPV, Volterra, and neural network models), and techniques for fitting nonlinear models to data.

Project Students are encouraged to bring data sets from their personal research to use in the course project. Many students have used the techniques from past offerings of this course to enhance their MS and PhD research.

ME548 APPLIED NONLINEAR DYNAMICS FALL 2014

Instructor: Prof Gábor Orosz
Department of Mechanical Engineering
Autolab G034, orosz@umich.edu

Lectures: Tu 9:00pm - 10:30pm, 1005 DOW
Th 9:00pm - 10:30pm, 1005 DOW

Recitation: Th 4:30pm - 6:00pm, TBA

Office hours: W 10:00am - 12:00am, , Autolab G034

Prerequisites: An undergraduate level course in dynamics/vibrations/control, for example, ME360. You are expected to have knowledge of linear algebra and differential equations.

Course books: D. W. Jordan and P Smith, *Nonlinear Ordinary Differential Equations*, 4th edition, Oxford University Press, 2007, http://th.if.uj.edu.pl/~biernat/ksiazki/

P. Glendinning, *Stability, Instability and Chaos: An Introduction to the Theory of Nonlinear Differential Equations*, Cambridge University Press, 1994

Additional reading: J. Guckenheimer and P. Holmes, *Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields*, Springer, 1997

Y. A. Kuznetsov, *Elements of Applied Bifurcation Theory*, 2nd edition, Springer, 1998

S. Wiggins, *Introduction to Applied Nonlinear DynamicalSystems and Chaos*, 2nd edition, Springer, 2003

Karl J. Astrom & Richard M. Murray, *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, 2008
http://www.cds.caltech.edu/~murray/amwiki/index.php/Main_Page

S. H. Strogatz, *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering*, Perseus Books Publishing, 1994

M. Gruiz and T. Tel, *Chaotic Dynamics: An Introduction Based on Classical Mechanics*, Cambridge University Press, 2006

B. D. Hassard, N. D. Kazarinoff, and & Y.-H. Wan, *Theory and Applications of Hopf bifurcation*, Cambridge University Press, 1981

Course description: Geometrical representation of the dynamics of nonlinear systems. Stability and bifurcation theory for autonomous and periodically forced systems. Chaos and strange attractors. Introduction to pattern formation. Applications to various problems in rigid-body dynamics, flexible structural dynamics, fluid-structure interactions, fluid dynamics, and control of electromechanical systems.

Website: We will maintain a course website on which we will post material (assignments, solutions, handouts, etc.) as well as announcements. You can access our course website at https://ctools.umich.edu/portal

The Engineering Honor Code: http://www.engin.umich.edu/students/honorcode/
No member of the community shall take unfair advantage of any other member of the community.

Assignments: Eleven homework assignments will be set during the term that will be posted on the course's website. Homework sets are **due no later than the start of class on Thursdays**, and late homework will NOT be accepted. The lowest homework score for the term will be dropped. Homework solutions will be available through the course web site. You are encouraged to discuss and work on homework together but the final document must represent your own understanding of the material.

Examinations:	Midterm Exam:	Oct 22 (Wed), 6:00pm - 8:00pm
	Final Exam:	Dec 17 (Wed), 1:30pm - 3:30pm

The exams will be closed book. One sheet of notes (8.5" by 11") will be permitted for the exams (one-sided for the midterm and double-sided for the final).

Grading:	Homework	30%
	Midterm Exam	30%
	Final Exam	40%

No class on: Oct 14 (Tu) – Fall study break
Oct 23 (Th) – Instructor traveling
Nov 27 (Th) – Thanksgiving

Make up class: Oct 8 (Wed), 4:30pm – 6:00pm

Additional rules: no laptops, cell phones, ipods, ipads, etc. during the class

Course Schedule (tentative 4/9/14):

LECTURE	DATE	TOPICS	READING	HW DUE DATES
1	Tu 9/2	Introduction to course, Constraints in mechanical systems		
2	Th 9/4	Virtual power, Lagrange equations of the second kind		
3	Tu 9/9	Lagrange equations of the second kind		
4	Th 9/11	Nonlinearities in mechanical systems, Invariant objects in state space	**JS 1, GL 1**	HW #01
5	Tu 9/16	Planar dynamical systems, phase plane plots	**JS 1,2,3, GL 5**	
6	Th 9/18	Linear dynamics in n dimension	**GL 3, AM 5**	HW #02
7	Tu 9/23	Nonlinear dynamics in n dimension, Poincare linearization, Manifolds	**GL 4**	
8	Th 9/25	Lyapunov stability, Lyapunov function, LaSalle-Krasovskii invariance principle	**AM 4, GL 2**	HW #03
9	Tu 9/30	Lyapunov stability for conservative mechanical systems	**AM 4, GL2**	
10	Th 10/2	Metronom. steady-state bifurcations (Pitchfork, Fold)	**JS 12**	HW #04
11	Tu 10/7	Steady-state bifurcations – Normal Forms	**GL 8**	
12	**W 10/8**	**MAKE UP lecture, 4:30pm-6:00pm** Nonlinear dynamics in n dimension with parameters, Center manifold reduction	**JS 12, GL 8**	
13	Th 10/9	Lienard and Bendixson criteria and stick-slip oscillations	**JS 11, GL 5**	HW #05
	Tu 10/14	**FALL STUDY BREAK no class**		
14	Th 10/16	Hopf bifurcation theorem, Hopf normal form calculation, Bautin formula	**HKW**	HW #06
15	Tu 10/21	Hopf normal form calculation for stick-slip oscillations *Videos*	**HKW**	
	W 10/22	**MIDTERM EXAM, 6:00-8:00pm**		
	Th 10/23	**PROF TRAVELS no class**		
16	Tu 10/28	Nonlinear oscillations in conservative systems Poincare-Linstedt method	**JS 5,7**	
17	Th 10/30	Nonlinear oscillations in periodically forced systems	**JS 5,7**	HW #07
18	Tu 11/4	Parametric excitation, Mathieu Equation, Floquet theory	**JS 9, GL 3.5, 6.3, 6.4**	
19	Th 11/6	Parametric excitation, Mathieu Equation, Floquet theory	**JS 9, GL 3.5, 6.3, 6.4**	HW #08
20	Tu 11/11	Mathieu Equation with damping, Stability of oscillations in periodically forced systems	**JS 9**	

21	Th 11/13	Stability of oscillations in autonomous systems, Poincare maps, Application to Hopf normal form	**GL 6**	HW #09
22	Tu 11/18	Bifurcations and normal forms of maps (fold, flip, Neimark-Sacker), Resonances and Arnold Tongues	**GL 9**	
23	Th 11/20	Numerical continuation of equlibria, Newton method, Predictors and correctors, Pseodu-arclenght parameterization	**Handout**	
24	Tu 11/25	Continuation of periodic orbits, Boundary-value problems, Collocation Methods	**Handout**	HW #10
	Th 11/27	**THANKSGIVING**		
25	Tu 12/2	Chaos in dissipative and conservative system,	**GT**	HW #11
26	Th 12/4	Routes to chaos (period doubling, homoclinic tangency)	**GT**	
27	Tu 12/9	Micro-chaos in digital control	**GT**	HW #12
	W 12/17	**FINAL EXAM, 1:30-3:30pm**		

HW #01 – Solving ordinary differential equations analytically and numerically
HW #02 – Deriving Lagrangian equations of the second kind
HW #03 – Phase portraits of two-dimensional systems
HW #04 – Linearization and Jordan normal forms for n-dimensional systems,
calculating stable and unstable manifolds
HW #05 – Lyapunov stability and Dirichlet theorem
HW #06 – Steady-state bifurcations (fold, pitchfork, transcritical) and center manifold reduction
HW #07 – Lineard and Bendixson criteria, Hopf bifurcation calculation and center manifold reduction
HW #08 – Poincare-Lindstedt method for conservative and dissipative systems,
Subharmonic and ultraharmonic resonance
HW #09 – Floquet theory and Mathieu equations
HW #10 – Fold, flip and Neimark –Sacker bifurcations for maps and center manifold reduction
HW #11 – Numerical continuation and applications of DDE-biftool
HW #12 – Chaotic dynamics

Each HW will be preceded by a recitation on the topic