Winter 2017
Updated November 30 2016

AERO 575 Flight and Trajectory Optimization. [Kolmanovsky]
AERO 550 (EECS 560) (ME 564) [Scruggs]
AERO 551 (EECS 562) [Meerkov]
AERO 580 (EECS 565)
    Section 1 [Freudenberg]
    Section 2 [Bernstein, Girard]
AERO 584 Navigation and Guidance of Aerospace Vehicles. [Panagou]

EECS 419 Electric Machines and Drives[Hofmann]
EECS 460 [Ozay]
EECS 461 [Cook, Freudenberg]
EECS 463 [Hiskens]
EECS 467 [Jenkins] Autonomous Robotics
EECS 498-001 [Revzen] Hands on Robotics
EECS 560 (AERO 550) (ME 564) [Scruggs]
EECS 561 (ME 561) [Gillespie]
EE 562 (AERO 551) [Meerkov]
EECS 565 (AERO 550)
    Section 1 [Freudenberg]
    Section 2 [Bernstein, Girard]
EECS 567 (ME 567) [Gillespie] Robot Kinematics and Dynamics
EECS 598-002 [Avestruz] Advanced Topics in Design of Power Electronics
EECS 598-003 [Berenson] Motion Planning
EECS 598-005 [Hiskens] Grid Integration of Renewable Energy

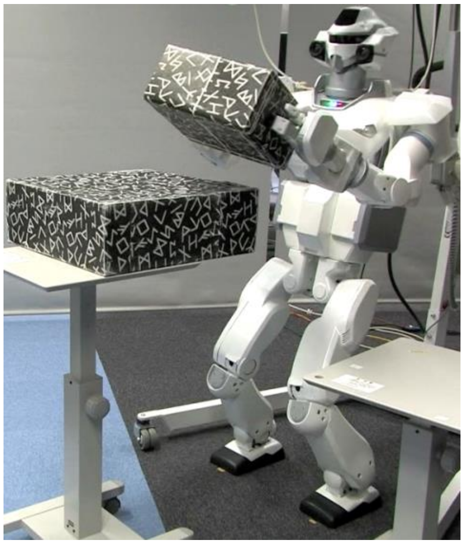
ME 461 [Tilbury] Automatic Control
ME 542 [Orosz] Vehicle Dynamics
ME 543 [Remy] Analytical and Computational Dynamics 1
ME 548 [Orosz] Applied Nonlinear Dynamics
ME 561 (EECS 561) [Gillespie]
ME 564 560 (AERO 550) (EECS 560) [Scruggs]
ME 565 [Siegel] Battery Systems and Control
ME 566 (Peng) Hybrid Electric Vehicles

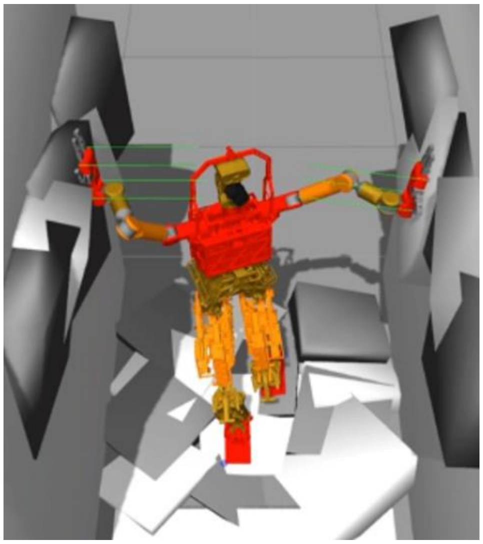
ME 567 (EECS 567) [Gillespie] Robot Kinematics and Dynamics

ROB 550 [Atkins] Robotics Systems Laboratory

Interesting IOE courses
IOE 510 - Linear Programming I
IOE 511- Continuous Optimization Methods
IOE 614- Integer Programming

EECS 598 Motion Planning – Winter 2017



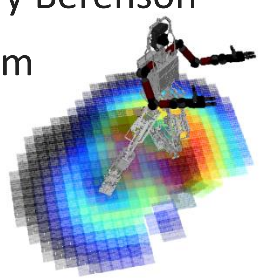


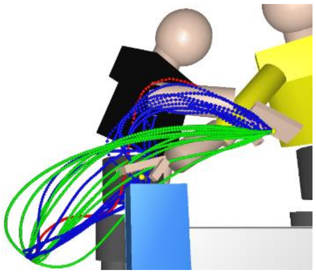
Course Description: Motion planning is the study of algorithms that reason about the movement of physical or virtual entities. These algorithms can be used to generate sequences of motions for many kinds of robots, robot teams, animated characters, and even molecules. This course will cover the major topics of motion planning including (but not limited to) planning for manipulation with robot arms and hands, mobile robot path planning with non-holonomic constraints, multi-robot path planning, high-dimensional sampling-based planning, and planning on constraint manifolds. Students will implement motion planning algorithms in open-source frameworks, read recent literature in the field, and complete a project that draws on the course material.

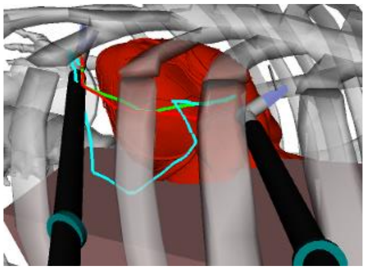
Pre-requisites: Undergraduate Linear Algebra, experience with 3D geometry, and significant programming experience.

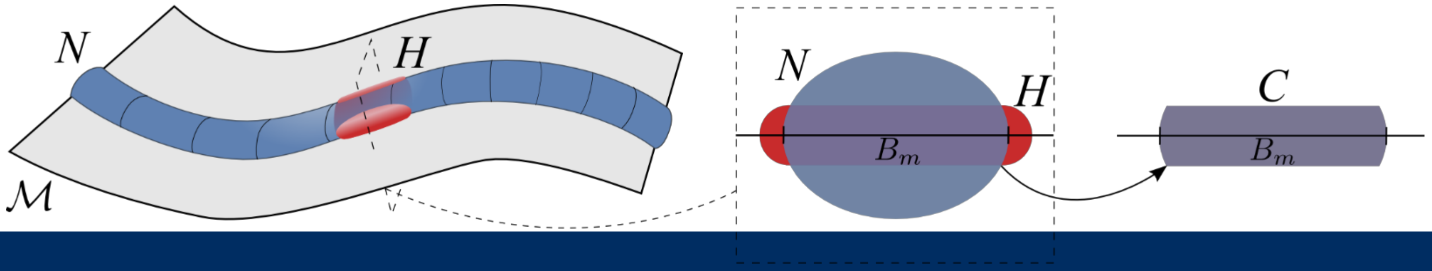
Instructor: Prof. Dmitry Berenson

Time: MW 2:30-4:00pm









ME542 VEHICLE DYNAMICS (AND CONTROL) WINTER 2017

Instructors:

Prof Gábor Orosz
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Lectures: Tu 1:30pm - 3:00pm, CHRYS 151
Th 1:30pm - 3:00pm, CHRYS 151

Recitation: Fr 2:00pm - 3:30pm, CHRYS 151

Office hours: M TBA
Tu TBA
We 11:00am - 12:00pm, Autolab G034

Distance learning students are required to attend the office hours in **at least every second week**.

Prerequisites: You are expected to have knowledge of vector calculus, matrices algebra, differential equations, and rigid body dynamics (for example, ME 440 or ME 540).

Reading:

K. Popp and W. Schiehlen, *Ground Vehicle Dynamics*, Springer, 2010
http://link.springer.com/book/10.1007/978-3-540-68553-1
D. Schramm, M. Hiller, R. Bardini, *Vehicle Dynamics: Modeling and Simulation*, Springer, 2014
http://link.springer.com/book/10.1007/978-3-540-36045-2
R. Rajamani, *Vehicle Dynamics and Control*, 2nd edition, Springer, 2012
http://link.springer.com/book/10.1007/978-1-4614-1433-9
A. G. Ulsoy, H. Peng, M. Çakmakci, Automotive Control Systems, Cambridge Univ. Press 2012
http://www.cambridge.org/us/academic/subjects/engineering/control-systems-and-optimization/automotive-control-systems
J. Y. Wong, *Theory of Ground Vehicles*, 4th edition, Wiley, 2008
http://www.wiley.com/WileyCDA/WileyTitle/productCd-0470170387.html
H. Baruh, *Applied Dynamics*, CRC Press, 2014
http://www.crcpress.com/product/isbn/9781482250732

Course description: Dynamics of the motor vehicle. Static and dynamic properties of the pneumatic tire. Mechanical models of single and double-track vehicles enabling prediction of their response to control forces/moments and external disturbances. Directional response and stability in small disturbance maneuvers. The closed-loop driving process. Behavior of the motor vehicle in large perturbation maneuvers. Ride phenomena treated as a random process.

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 canvas https://umich.instructure.com

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: Twelve 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 in paper format**. For distance learning students the deadlines are extended until **Sunday midnight EST** and they shall upload the scanned homeworks named **HW##_firstname_lastname.pdf** into their Drop Box on canvas. Late homeworks are accepted up to 72 hours after the deadline but 50% of the grade will be taken off. The lowest homework score for the term will be dropped. Homework solutions will be available through the course web site. Put on each homework sheet how much time you spent solving it for extra 2 points.

You are encouraged to discuss and work on homework together but the final document must represent your own understanding of the material.

If you find errors in your graded homework (e.g. scores do not add up, the grader missed a page etc.) you may ask for re-grade. You need to attach a sheet where you write up the issue and resubmit the homework to the professor within one week after receiving the graded homework.

Examinations: Midterm Exam: Mar 8 (Wed), 6:00 - 8:00pm, CHRYS 151
Final Exam: Apr 27 (Wed), 1:30 - 3:30pm, CHRYS 151

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%

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

Course Outline:

1. Longitudinal vehicle dynamics
1.1 Review of the Newton-Euler approach of modelling rigid body dynamics
1.2 Modeling longitudinal vehicle dynamics
1.3 Adaptive cruise control design

2. Ride dynamics
2.1 Lagrange equations and their application to multi-body systems
2.2 Random processes
2.3 Quarter car model and suspension design
2.4 Half car model (bounce, pitch)
2.5 Passive and active suspension design

3. Vehicle handing
3.1 Nonholonomic systems and Appell equations
3.2 Bicycle model of vehicle steering
3.3 Lane keeping control
3.4 Lateral + roll dynamics

4. Tire models
4.1 Longitudinal and lateral and brush model
4.2 Stretched-string model
4.3 Magic formula

5. Vehicle handing with tires
5.1 Bicycle model with elastic tires
5.2 Steady state handling (oversteer, understeer)
5.3 Transient handling and lane keeping control
5.4 Lateral + roll dynamics

Course Schedule (tentative 11/24/16): **PS** = Popp-Schiehlen; **SHB** = Schramm-Hiller-Bardini, **R** = Rajamani, **UPC** = Ulsoy-Peng-Çakmakci)

LECTURE	DATE	TOPICS	READING	HW DUE DATES
1	Th 1/5	Introduction, Review of particle dynamics	Handouts	
2	Tu 1/10	Review of rigid body dynamics	**PS** 2.2-2.3, **SHB** 2	
3	Th 1/12	3D Dynamics of the Vehicle	**PS** 8.2-8.5	HW#01
4	Tu 1/17	Longitudinal Dynamics	**PS** 8.2-8.5 **R** 5.3-5.4	
5	Th 1/19	Cruise Control, Adaptive Cruise Control	Shah-Orosz 2012	HW#02
6	Tu 1/24	Constraints and Lagrange Equations	**SHB** 4.1-4.5 **PS** 2.3	
7	Th 1/26	Lagrange Equations	**SHB** 4.1-4.5 **PS** 2.3	HW#03
8	Tu 1/28	Quarter car models (1DOF, 2DOF)	**R** 10 **PS** 7.1-7.2.2	
9	Th 2/2	Quarter car model (2DOF), Half car model	**R** 10 **PS** 7.1-7.2.2	HW#04
10	Tu 2/7	Stochastic road excitation	**UPC** 4.4 **PS** 7.2.3.1-7.3 Scruggs 125-132	
11	Th 2/9	Stochastic road excitation	**UPC** 4.4 **PS** 7.2.3.1-7.3 Scruggs 125-132	HW#05
12	Tu 2/14	Suspension design and active suspension	**UPC** 16 Ulsoy-Hrovat-Tseng 1994	
13	Th 2/16	Nonholonomic systems and Lagrange equations	Wang-Pao 2003 Flannery 2004	HW#06
14	Tu 2/21	Bicycle model(s) of automotive steering	Astrom-Murray pp 51-53	
15	Th 2/23	Nonholonomic systems and Appell equations	Wang-Pao 2003 Flannery 2004	HW#07
	2/27–3/3	**WINTER RECESS**		
16	Tu 3/7	Appell equations and bicycle model(s) of automotive steering		
	W 3/8	**MIDTERM EXAM at 6-8pm**		
17	Th 3/9	Bicycle model(s) of automotive steering and steering control		

18	Tu 3/14	Ackermann steering, Off tracking, Articulated vehicles, Roll dynamics		
19	Th 3/16	Roll dynamics		HW#08
20	Tu 3/21	Tire models, Rolling resistance, Longitudinal brush model	**PS** 3.4.1, 3.4.4.1-3.4.4.3 **SHB** 7.3.1-7.3.4	
21	Th 3/23	Lateral brush model,	**PS** 3.4.1, 3.4.4.1-3.4.4.3 **SHB** 7.3.1-7.3.4	HW#09
22	Tu 3/28	Stretched string model, Combined lateral and longitudinal deformation	Takacs-Orosz-Stepan 2009 Takacs-Stepan 2012	
23	Th 3/30	Bicycle model(s) of automotive steering with brush tire	**PS** 9.1, **SHB** 10.1	HW#10
24	Tu 4/4	Steady state handling, Neutralsteer, Understeer, Oversteer	**PS** 9.1, **SHB** 10.1	
25	Th 4/6	Transient handling and steering control	**PS** 9.1, **SHB** 10.1	HW#11
26	Tu 4/11	Steering compliance, banking, differential braking		
27	Th 4/13	Roll dynamics, Rear wheel steering and four wheel steering		
28	Th 4/18	Review and Project Presentation		HW#12
	We 4/27	**FINAL EXAM at 1:30-3:30pm**		

HW#01 – Linear algebra and differential equations
HW#02 – Rigid body dynamics
HW#03 – Longitudinal dynamics
HW#04 – Lagrangian dynamics
HW#05 – Ride dynamics – Modeling and frequency response
HW#06 – Ride dynamics – Stochastic road excitation
HW#07 – Active Suspension Design
HW#08 – Steering and handling – Lagrangian and Appellian models
HW#09 – Steering and handling – Stability, control, sliding and rolling
HW#10 – Tire models – Longitudinal and lateral brush models
HW#11 – Tire models – Stretched string model and combined slip
HW#12 – Handling with tires

ME548 APPLIED NONLINEAR DYNAMICS WINTER 2017

Instructor: Prof Gábor Orosz
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Autolab G034
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GSI: Mr Sergei Avedisov
Dept. of Mechanical Engineering
Autolab G041
avediska@umich.edu

Lectures: Tu 10:30am - 12:00pm, CHRYS 151
Th 10:30am - 12:00pm, CHRYS 151

Recitation: Fr 3:30pm - 5:00pm, CHRYS 151

Office hours: M TBA
Tu TBA
W 11:00am - 12:00pm, 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:	Mar 8 (Wed), 6:00pm - 8:00pm
	Final Exam:	Apr 26 (Wed), 4:00pm - 6:00pm

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%

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

Course Schedule (tentative 11/23/16):

LECTURE	DATE	TOPICS	READING	HW DUE DATES
1	Th 1/5	Introduction to course, Constraints in mechanical systems		
2	Tu 1/10	Virtual power, Lagrange equations of the second kind		
3	Th 1/12	Lagrange equations of the second kind		
4	Tu 1/17	Lagrange equations of the second kind, Nonlinearities in mechanical systems	**JS 1**	HW#01
5	Th 1/19	Invariant objects in state space Planar dynamical systems, Phase plane plots	**JS 1,2,3, GL 1,5**	
6	Tu 1/24	Linear dynamics in n dimension	**GL 3, AM 5**	
7	Th 1/26	Nonlinear dynamics in n dimension, Poincare linearization	**GL 4**	HW #02
8	Tu 1/31	Manifolds, Lyapunov stability	**AM 4, GL 2,4**	
9	Th 2/2	Lyapunov function	**AM 4, GL2**	HW #03
10	Tu 2/7	Lyapunov stability for conservative mechanical systems	**AM 4, GL2**	
11	Th 2/9	Metronom. steady-state bifurcations (pitchfork, fold)	**JS 12**	HW #04
12	Tu 2/14	Steady-state bifurcations – Normal Forms	**GL 8**	
13	Th 2/16	Nonlinear dynamics in n dimension with parameters, Center manifold reduction	**JS 12, GL 8**	HW#05
14	Tu 2/21	Lienard and Bendixson criteria and stick-slip oscillations	**JS 11, GL 5**	
15	Th 2/23	Hopf bifurcation theorem, Hopf normal form calculation	**HKW**	HW#06
	2/27–3/3	**WINTER RECESS**		
16	Tu 3/7	Bautin formula, Hopf normal form calculation for stick-slip oscillations	**HKW**	
	We 3/8	**MIDTERM EXAM at 6-8pm**		
17	Th 3/9	*Videos*, Nonlinear oscillations in conservative systems, Poincare-Linstedt method	**JS 5,7**	

18	Tu 3/14	Nonlinear oscillations in periodically forced systems	**JS 5,7**	
19	Th 3/16	Parametric excitation, Mathieu Equation	**JS 9, GL 3.5, 6.3, 6.4**	HW#07
20	Tu 3/21	Floquet theory	**JS 9, GL 3.5, 6.3, 6.4**	
21	Th 3/23	Floquet theory, Ince-Strutt stability chart	**JS 9, GL 3.5, 6.3, 6.4**	HW#08
22	Tu 3/28	Mathieu Equation with damping, Stability of oscillations in periodically forced systems	**JS 9**	
23	Th 3/30	Stability of oscillations in autonomous systems, Poincare maps, Application to Hopf normal form	**GL 6**	HW#09
24	Tu 4/4	Bifurcations and normal forms of maps (fold, flip, Neimark-Sacker), Resonances and Arnold Tongues	**GL9**	
25	Th 4/6	Numerical continuation of equlibria, Newton method, Predictors and correctors, Pseodu-arclenght parameterization	**Handout**	HW#10
26	Tu 4/11	Continuation of periodic orbits, Boundary-value problems, Collocation Methods	**Handout**	
27	Th 4/13	Chaos in dissipative and conservative system Routes to chaos (period doubling, homoclinic tangency)	**GT**	
28	Tu 4/18	Micro-chaos in digital control, Review		HW#11
	W 4/26	**FINAL EXAM, 4:00-6:00pm**		

HW #01 – Solving ordinary differential equations analytically and numerically
HW #02 – Deriving Lagrange 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

Each HW will be preceded by a recitation on the topic