ME569: Powertrain Control

Fall 2014 (3 credits), Mon/Wed 10:30-12:00 DOW 1010

Instructor: Professor Stefanopoulou, annastef@umich.edu
Graduate Student Instructor: Sandro Nuesch, snuesch@umich.edu

Course statement: The course covers essential aspects of electronic engine control followed by recent control problems arising in direct injection, variable valve timing, active boosting, and flexible-fuel combustion. The course includes models and feedback control design of spark ignition (gasoline), compression ignition (diesel), and thermal ignition (HCCI) engines as well as a quick overview of control issues arising in electric powertrains with batteries, capacitors, and fuel cells. We will practice system identification, averaging, feedforward, feedback, multivariable control, and estimation.
* See MATH and control requirements below.
**Matlab and Simulink and other Mathworks toolboxes will be used.

Home Page: (https://ctools.umich.edu/portal): Lecture notes and handouts will be posted in ctools.
Email: CTools emailing and Piazza posts will be used to send you announcements. You can always email me with questions **(use ME569F14 in your message subject)** but we prefer piazza for questions or class discussion: https://piazza.com/umich/fall2014/mecheng569f14/home
*First describe the problem you are facing in the text of your post. This will help me when I travel and cannot open attachments or when I use my phone. You could **attach a pdf** with your question (m-file, sml-file, and resulting graphs in one PDF). If I need more info, I will ask you to send me your working m- and sml-file.
** I typically try to respond **within a day**, but my ability to help declines as e-mail volume increases; so please do not wait until the last day. I **typically cannot help during the due day** of the HW because I have meetings during the day.

Textbook:
"Introduction to Modeling and Control of Internal Combustion Engine Systems" by L. Guzzella and C.H. Onder, Springer-Verlag 2004, ISBN 3-450-22274 http://mirlyn.lib.umich.edu/Record/008158097
And/Or
"Modeling and Control of Engines and Drivelines (Automotive Series)" by Lars Eriksson and Lars Nielsen (Feb 27 2014), ISBN: 1118479998 (available online) http://mirlyn.lib.umich.edu/Record/012844556

Optional (available in the Library or online):
1. Internal Combustion Engine Fundamentals, Heywood, McGraw-Hill, 1988
3. Automotive Control Systems, U. Kiencke, and L. Nielsen, SAE and Springer-Verlag,
4. G. F. Franklin, J. D. Powell, A. Emami-Naeini, "Feedback Control of Dynamic Systems," Prentice Hall (available in CTools in pdf; please do not share outside class)

Grading: HW (30%), Exam 1 (35%), Exam 2 (35%)
Office Hours: Mon 4-5 (GSI), Tues 4-5 (Prof) & 5-6 (GSI), Fri 2:30-3:30 (Prof)
Prof. office hours @ 2044 Auto Lab (AL), whereas the GSI @ 3028 Phoenix Memorial Lab (PML)

Homework: Almost every week! The lowest homework score will be dropped. You may discuss the homework assignments with each other and with the instructor, but you **must write your own solutions** to the homework, which reflect your own understanding of the material. The homework has to be returned in paper **at the beginning of class the day it is due**.

Exam: Exam 1: **Wed Oct 15** (xx:xx-yy:yy @ zzzz)
Exam 2: If Written, Scheduled for Mon Dec 15, 4:00-6:00pm,
but might have an oral exam on Thu-Fr Dec 4-5 in the evening hours
(depends on the class size after Exam 1)

Course Outline:

Chapter 1: Background and Motivation

Chapter 2: Control Oriented Modeling – Manifold Filling Dynamics

The Basics: Ideal Gas Law, Mass Conservation, Energy Conservation
The Assumptions: Space-averaging and Cycle-averaging
The Fidelity: Detailed and Mean-Value Models
Event-averaging in time- and crankangle-domain
Regression and mapping data
Linearization

Chapter 3: Basic Internal Combustion Engine Control Functionalities

Air-to-Fuel Ratio Control
For Fast Response: Feedforward Control with Air Charge Estimation
For Accurate Response: Feedback with Oxygen Sensors (Linear and switching sensor)
Cylinder-to-cylinder Maldistribution (Lifting Control technique)

Idle Speed Control
The Three Devils: Unmeasured Disturbance, Actuator Authority, and Model Uncertainty
The Tools: Coordinated Feedforward and Feedback
Adaptive Control Methodology
Spark Compensation—sequential loop closing

Spark Timing Control
The Easy Way: The Look-Up Table
The Right Way: Feedback with Knock Sensor
The Other Right Way: Combustion sensing, Estimation and HCCI control

Exhaust Gas Recirculation
External EGR Control
Internal EGR Control
Control of Variable Camshaft Timing and Variable Valve Timing

Boosting
The standard: Control of Wastegate
The challenge: Coordinated control of VGT and EGR
The fun: Optimal Control of Electrically Assisted Turbocharging

Chapter 4: Control of Advanced Combustion Engines

Lean Combustion & Exhaust Aftertreatment Control
Ethanol-Gasoline Flex Fuel Vehicles (FFV)
Low Temperature Combustion Control (HCCI, PCCI, PCI)
On-board Diagnosis

Chapter 5: Drive Cycle Simulation for Fuel Efficiency Estimation

~~**Chapter 6: Control of Electrochemical Engines**~~

~~**Control of Power from Fuel Cells**~~
~~Polymer Electrolyte Membrane (Hydrogen-based) Principles~~
~~The air, the hydrogen, the cooling, the water management~~
~~Solid Oxide Fuel Cell and Fuel Processing~~

~~**Battery:** Principles, Types and the application~~
~~The electrical view- Equivalent Circuit Models and SOC estimation~~
~~The thermal view: Joules heating, Cooling, Thermal Runaway~~

				Topic		out	due				
	week	Date	D								
1	1	3-Sep	W	Intro	review	1					
2	1	8-Sep	M	Throttled Breathing Model							
3	2	10-Sep	W	Manifold Filling Dynamics	model	2	1	adiabatic+WOT-			
4	2	15-Sep	M	Air Charge Estimation+MAF/MAP sensor				MAF+MAP, eEGR, iEGR			
5	3	17-Sep	w	Sensitivity, FuelPudle, Hot Wire Anemometer	estim+sens	3	2				
6	3	22-Sep	m	AFR feedback UEGO							
7	4	24-Sep	w	Idle Speed Control (ISC)	AFR+SW	4	3				
8	4	29-Sep	m	ISC-Throttle							
9	5	1-Oct	w	ISC-Throttle & Spark	ISC-Throttle	5	4				
10	5	6-Oct	m	ISC-TISO State Space							
11	6	8-Oct	w	review	ISC-SS	6	5	review			
br	6	13-Oct	m	break							break
12	7	15-Oct	w	exam				exam			CHBC
13	7	20-Oct	m	Flex Fuel Vehicles (FFV)							
14	8	22-Oct	w		FFV	7	6	read paper from DSCC			DSCC
15	8	27-Oct	m	lambda estimator+Compression Detection							
16	9	29-Oct	w	Variable Valve/Cam Timing	VCT timecst	8	7				
17	9	3-Nov	m	Jake Brake							
18	10	5-Nov	w	Turbocharging	GTDI	9	8				
19	10	10-Nov	m	Model-Tutorial				Pat G			Hopkinson
20	11	12-Nov	w	Throttle-Wastegate							
21	11	17-Nov	m	Diesel+EGR/VGT							
22	12	19-Nov	w	Spark Ignition, Combustion, Knock	knCntr+CV	10	9				
23	12	24-Nov	m	Cycle-to-Cycle Variability							
24	13	26-Nov	w	Knock Control						BeforeThx	
25	13	1-Dec	m	HCCI							
26	14	3-Dec	w	Aftertreatment: Three Way Catalyst Oxygen Storage			10	Sandro S			
27	14	8-Dec	m	Drive Cycle Simulations (Vehicle Model+Switch Mode)				Sandro S			China
28	15	10-Dec	w	OBD				Mike H.		last cla	China
		15-Dec	m							schexm 4:00-6:00pm	

Open to graduate or senior students in Mechanical, Electrical, Chemical, Aerospace, and Marine Engineering with basic control engineering and dynamics background (ME360 and ME461 equivalent). Permission from the instructor is required for senior undergraduate students.

As you know ME461 is a pre-requisite for this class. Below is a list of the MATH and Controls notions I will be using a lot in the class and you should know.

1. Ordinary Differential equations

2. Linearization

3. Laplace and transfer functions (poles, zeros, DC gain)

4. Frequency Domain Representation of systems and signals: bandwidth, roll-off rate, DCgain, natural, damped frequencies ...

5. Stability, characteristic equation, eigenvalues

6. Time responses, overshoot, undershoot, settling time, damping ratio, time constant, rise time ...

7. States, state-space representation

8. Basics of PID controllers, Root locus ...

Items 1-6 are a must! Do not take this class if you do not know or feel comfortable with 1-6. You can probably study items 7-8 and catch up while taking this class.