EGR 598-Topic: Vehicle Dynamics and Control
The Polytechnic School
Ira A. Fulton Schools of Engineering
Fall 2019 (Updated)

Instructor: Dr. Yan Chen.
Lectures: MW 4:35 – 5:50 PM; SANCA 151, Polytechnic Campus.
Computer Room: MWF 1:00 – 7:00 PM; SANCA 153, POLY (SunCARD Access).
Office & Contacts: PRLTA 330M, Tel: 727-5123, email: yanchen@asu.edu.
Office Hours: MW 3:00 – 4:00 PM, plus *appointments by email*.
Prerequisites: EGR 465, or control of linear/nonlinear systems, or instructor's permission.

Course Overview and Description

This course aims to introduce modeling, estimation, control, and optimization of typical vehicle (sub)system dynamics. Recent advances in automotive technology, such as vehicle electrification, connected and automated/autonomous driving, further complicate vehicle (sub)systems as nonlinear multi-input-multi-output systems with un-modeled dynamics, structure uncertainties, and external disturbances. Thus, effective vehicle control design requires to sophisticatedly combine advanced control theory with knowledge of vehicle system characteristics. To achieve this goal, the course will introduce a variety of modeling, advanced control, estimation, and optimization techniques for typical vehicle (sub)systems. Applications of control theories to various vehicle (sub)system dynamics will be discussed through examples inspired from pertinent research projects. Co-simulation between Matlab/Simulink and CarSim® (a well-recognized professional software of vehicle dynamics in both industry and academia) will be extensively utilized for vehicle dynamics analysis, vehicle control design and verification, and automated driving.

Tentative Topics and Number of Lectures

- Overview of current vehicle control systems: sensors, actuators, and controls (2)
- Introduction to static and dynamic tire models (2)
- Vehicle motions and control-oriented dynamic models (2)
- Introduction to CarSim® (2)
- Advanced estimation, nonlinear control, and optimization techniques (8)
- Tire-road friction coefficient estimation (2)
- Safety, energy efficiency, and mobility of next-generation automated vehicles (2)
- Regenerative braking control and optimization for electrical vehicles (2)
- Active safety control of vehicle roll motion (2)
- Stability region estimation and control for automated vehicles (2)
- Control and optimization of over-actuated vehicles (2)
- Term Project – mid-term presentation and final report submission (2)

Total: 30

Course Objectives and Learning Outcomes:

Control design of ground vehicle dynamics, modeled as nonlinear multi-input-multi-output (MIMO) systems, faces great challenging for real applications by considering uncertainties and disturbances, especially due to recent advances in automotive engineering that involve more and advanced controllers, sensors, and actuators. To understand the complex physical systems, fundamental and important vehicle (sub)systems and components need to be first analyzed in terms of control oriented models (COM). Based on the developed COM, advanced control theory will be applied to solve the control problems utilizing the characteristics of physical systems. High-fidelity software about vehicle dynamics simulation that is also widely used in both academic research and industrial development, CarSim®, will be applied and integrated with Matlab/Simulink to validate control design, estimation algorithms, and optimization results.

Once students have completed this course, students will be able to

- Understand and be able to develop COM of different important vehicle dynamics;
- Understand and analyze vehicle COM using Matlab/Simulink;
- Understand and get familiar with high-fidelity vehicle dynamics simulation software CarSim®;
- Understand and be able to apply advanced control, estimation, and optimization techniques for vehicle nonlinear dynamics;
- Understand and be able to study some state-of-the-art research related to (hybrid) electric vehicles, autonomous and/or connected vehicles;
- Run co-simulation between Matlab/Simulink and CarSim® to validate the control design;
- Present project results professionally as in a IEEE or ASME conference;
- Write a project report professionally in the format of a IEEE or ASME conference paper;
- Prepare and get ready for starting a career in automotive industry and/or as a control engineer;

Textbook and Reference Books
No textbook will be required. Lecture notes based on reference books and literature will be available. The reference books are listed as follows.
1. Rajamani, "Vehicle Dynamics and Control," Springer, 2nd Ed., 2012.
2. Wong, "Theory of Ground Vehicles", John Wiley & Sons, 4th Ed., 2008.
3. Johansson and Rantzer, "Nonlinear and Hybrid Systems in Automotive Control," Springer, 2002.
4. Jazar, "Vehicle Dynamics Theory and Application," Springer, 2009.
5. Khalil, "Nonlinear Systems", Prentice Hall, 2nd+ Ed., 2002.
6. Slotine and Li, "Applied Nonlinear Control", Prentice Hall. 1991.
7. J. Nocedal and S. Wright, "Numerical Optimization," Springer, 2006.
8. U. Kiencke and L. Nielsen, "Automotive Control Systems," Springer, 2005.
9. V. Utkin, J. Guldner and J. Shi, "Sliding Mode Control in Electro-Mechanical Systems," CRC Press, 2nd Ed. 2009.

Grading Policy
Please bring any concerns about grading to me as soon as possible if the questionable item has been handed back. Letter grades of an A-E grading scale with +/- grading (e.g. A+, A, A-) will

be assigned based on a performance curve of the class. The following allocation will be used to determine the final score:

- Attendance: 10%
- Homework: 60% (15% each, total 4)
- Term Project: 30% (presentation 15% + report 15%)

Homework
About 4 homework will be assigned through the semester. Please bring your homework solutions to the lecture and *no late homework will be accepted*. Please write the answers neatly, especially in sketches and diagrams. Include a cover sheet with your name and assignment number and write only on the front side of the paper (not both sides). Box in your answer and show all units, especially on plots. Staple the homework in the upper left corner and leave unfolded. Matlab/Simulink simulation studies will be involved in the homework assignments.

Term Project
A term project, assigned or student self-proposed (encouraged), will be focused on the application of the learned control techniques in this class to any vehicle dynamic control problems. If you want to propose a term project topic, which is encouraged, please submit a short (no more than 1 page) proposal by the end of the 4th week of the class. It will be individual project.

Software Simulation Package
There are multiple computer seats of CarSim® vehicle dynamics simulation package available in the computer room SANCA 153, on Polytechnic campus. SunCARD access will be required.

General Information
Academic Integrity
Students in this class must adhere to ASU's academic integrity policy, which can be found at https://provost.asu.edu/academic-integrity/policy). Students are responsible for reviewing this policy and understanding each of the areas in which academic dishonesty can occur. In addition, all engineering students are expected to adhere to both the ASU Academic Integrity Honor Code and the Fulton Schools of Engineering Honor Code. All academic integrity violations will be reported to the Fulton Schools of Engineering Academic Integrity Office (AIO). The AIO maintains record of all violations and has access to academic integrity violations committed in all other ASU college/schools.

Copyright
Course content, including lectures, are copyrighted materials and students may not share outside the class, upload to online websites not approved by the instructor, sell, or distribute course content or notes taken during the conduct of the course (see ACD 304–06, "Commercial Note Taking Services" and ABOR Policy 5-308 F.14 for more information).

You must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum, material that is not the student's original work, unless the students first comply with all applicable copyright laws; faculty members reserve the right to delete materials on the grounds of suspected copyright infringement.

Policy against threatening behavior, per the Student Services Manual, SSM 104–02
Students, faculty, staff, and other individuals do not have an unqualified right of access to university grounds, property, or services. Interfering with the peaceful conduct of university-related business or activities or remaining on campus grounds after a request to leave may be considered a crime. All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students.

Disability Accommodations for Students
Students who feel they may need a disability accommodation(s) in class must provide documentation from the Disability Resource Center to the class instructor verifying the need for an accommodation and the type of accommodation that is appropriate. Students who desire accommodations for a disability should contact DRC as early as possible (i.e., before the beginning of the semester) to assure appropriate accommodations can be provided. It is the student's responsibility to make the first contact with the DRC. Qualified students who wish to request an accommodation for a disability can contact their campus DRC at: http://www.asu.edu/studentaffairs/ed/drc/. ASU also offers support services through Counseling (http://students.asu.edu/counseling).

Drop and Add Dates/Withdrawals
Please refer to the academic calendar on the deadlines to drop/withdraw from this course. Consult with your advisor and notify your instructor if you are going to drop/withdraw this course. If you are considering a withdrawal, review the following ASU policies: Withdrawal from Classes, Medical/Compassionate Withdrawal.

Incompletes
A mark of "I" (incomplete) is given by the instructor when you have completed most of the course and are otherwise doing acceptable work but are unable to complete the course because of illness or other conditions beyond your control. You are required to arrange with the instructor for the completion of the course requirements. The arrangement must be recorded on the Request for Grade of Incomplete form (http://students.asu.edu/forms/incomplete-grade-request).

Religious Accommodations for Students:
In accordance with ACD 304-04 students who need to be absent from class due to the observance of a religious holiday or participate in required religious functions must notify the faculty member in writing as far in advance of the holiday/obligation as possible. Students will need to identify the specific holiday or obligatory function to the faculty member. Students will not be penalized for missing class due to religious obligations/holiday observance. The student should contact the class instructor to make arrangements for making up tests/assignments within a reasonable time.

Missed Classes Due to University-Sanctioned Activities
In compliance with ACD 304-02 students who participate in university-sanctioned activities that require classes to be missed, should be given opportunities to make up examinations and other graded in-class work. However, absence from class or examinations due to university-sanctioned

activities does not relieve students from responsibility for any part of the course work required during the period of the absence.

Harassment and Sexual Discrimination
Arizona State University is committed to providing an environment free of discrimination, harassment, or retaliation for the entire university community, including all students, faculty members, staff employees, and guests. ASU expressly prohibits discrimination, harassment, and retaliation by employees, students, contractors, or agents of the university based on any protected status: race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, and genetic information.

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at https://sexualviolenceprevention.asu.edu/faqs.

Mandated sexual harassment reporter: As an employee of the University I am considered a mandated reporter and therefore obligated to report any information regarding alleged acts of sexual discrimination that I am informed of or have a reasonable basis to believe occurred.

ASU Counseling Services, https://eoss.asu.edu/counseling, is available if you wish to discuss any concerns confidentially and privately.

Syllabus Disclaimer:
The course syllabus is an educational contract between the instructor and students. Every effort will be made to avoid changing the course schedule but the possibility exists that unforeseen events will make changes necessary. The instructor reserves the right to make changes to the syllabus as deemed necessary. Students will be notified in a timely manner of any syllabus changes via email, or in the Announcements section on Blackboard.

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Academic Calendar (Fall 2019)
(refer to https://students.asu.edu/academic-calendar#fall19)

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Classes Begin	August 22, 2019
Drop/Add Deadline without College Approval	August 28, 2019
Labor Day – University Closed	September 2, 2019
Fall Break – Classes Excused	October 12-15, 2019
Course Withdrawal Deadline	November 6, 2019
Veterans Day – University Closed	November 11, 2019
Thanksgiving Holiday	November 28-29, 2019
Classes End	December 6, 2019
Study Day	December 7-8, 2019