ECE 760 Advanced Topics in Control Systems

Winter 2023 - January 05 to April 12

Class time: Friday 10:00-12:50   Location: ECE W3-087

Instructor:

Mahdi Tavakoli, PhD, P.Eng
780-492-8935
mtavakol@ualberta.ca
13-356 DICE
Office Hours: Tuesday & Thursdays 11:00-11:55

Course Description:

*3 (fi 6) (either term, 3-0-0)

Prerequisites: Linear algebra (a good understanding),
Linear control (a good understanding),
Nonlinear control (a preliminary understanding),
Introductory robotics (a preliminary understanding).

Course synchronous and asynchronous content delivery schedule:

The course will be delivered in-person.

TA Information:

Yafei Ou (yafei.ou@ualberta.ca)

Course Objectives & General Content:

Course title: Robotics: Modelling, Planning and Control.

The course discusses advanced modelling, planning and control methods for robots. Robot control cannot be considered as a straightforward extension/application of general control methods due to the particular dynamics of robotic systems and specialized training is required for students.

Topics covered include motion, force, and impedance control of manipulators. New robotic problems such as mobile robots and continuum robots have precipitated new control theories. The course will start with kinematic and dynamic modelling of robots and then continue to cover some of the advanced control techniques developed for robots in a systematic manner. Topics to be covered include joint-space control including passivity-based, robust and adaptive control methods, task-space control including kinematic control, motion and force control including impedance control, and control of non-holonomic systems.

Learning Outcomes:

By the end of this course, students should be able to:

1. Fully understand the following topics:

   Robot kinematics
   Redundant robots kinematics
   Robot dynamics
   Properties, extensions, and uses of dynamic models
   Introduction to robot control
   Position regulation in joint space (free motion)
   Trajectory tracking in joint space (free motion)
   Cartesian control (free motion)
   Interaction modeling and control
   Trajectory learning
   Visual servoing (kinematic approach)

Marking Scheme:

Activity	(A)Synchronous	Due/Scheduled	Weight
Presentation of learning materials	Synchronous	Varies	30%
Participation & skills in class discussions	Synchronous	Varies	10%
Project outcomes and presentation	Synchronous	Varies	30%
Written problem solving	Synchronous	Varies	30%

The Faculty recommended grade point average for a 700 level course is 0.0. Instructors have the leeway to deviate from this average and can assign grades based on their own scheme. All grades are approved by the department chair (or delegate). The office of the Dean has final oversight on all grades.

Term Work

All term work solutions will be posted no later than the last day of classes. All term work will be returned to students by the final day of classes, with the exception of major term work due in the last week of classes. The latter will be returned by the day of the final examination or the last day of the examination period if there is no final examination in the course as per university policy; instructors will make accommodations to return these term work. It is the responsibility of the student to pick up all their term work at the specified time and place. Any unreturned term work, shall be retained and then shredded six months after the deadline for reappraisal and grade appeals. Final examinations will be kept for one year as required by university guidelines and the Government of Alberta's Freedom of Information and Protection of Privacy Act.

Additional Notes

Each student will be assigned some material to read and present to the rest of the class. All class activities will be moderated by the instructor.

Students will have a term project to do. As part of the term project, the modelling, planning and control methods under investigation need to be applied to the case studies.

Problem sets will be given to students to solve.

Calculator Policy

Approved programmable or approved non-programmable calculators are permitted in examinations. Any calculator taken into an examination must have a sticker identifying it as an acceptable programmable calculator (green sticker) or non-programmable calculator (gold sticker). Students can purchase calculators at the University Bookstore with the stickers already affixed. Calculators purchased elsewhere can be brought to the Student Services where the appropriate sticker will be affixed to the calculator.

Text and References (Mandatory):

Textbook #1: H. J. Marquez, Nonlinear Control Systems: Analysis and Design, Wiley, 2003.

Textbook #2: J. J. Craig, Introduction to Robotics: Mechanics and Control, Pearson, 4th edition, 2018.

Textbook #3: B. Siciliano, L. Sciavicco, G. Villani, G. Oriolo, Robotics: Modelling, Planning and Control, Springer, 3rd Edition, 2009.

Text and References (Recommended):

As supplementary reading material, students may choose to self-study Chapters 2-6 of Theory of Robot Control by Canudas de Wit, Carlos, Siciliano, Bruno, Bastin, Georges (Eds.), Chapter 7 (Nonholonomic Behavior in Robotic Systems) and Chapter 8 (Nonholonomic Motion Planning) of A Mathematical Introduction to Robotic Manipulation by Richard M. Murray, Zexiang Li and S. Shankar Sastry.

Website:

eClass

Did you know that the University of Alberta has various low-to-no-cost services to help students succeed? Visit http://www.deanofstudents.ualberta.ca/ for information about the academic, wellness, and various other support services available to U of A students. It's never too early or too late to seek help!

	Textbook (Ch.Sect.Par)	Lecture
	Textbook #1	
Nonlinear control fundamentals	3	Lyapunov Stability: Autonomous Systems
	4	Lyapunov Stability: Nonautonomous Systems
	Textbook #2	
Robot kinematics fundamentals	1	Robotics overview
	2	Spatial descriptions & transformations
	3	Forward kinematics
	4	Inverse kinematics
	5	Jacobians
	Textbook #3	
Redundant robots	2.10.2, 3.4, 3.5, App. A.7, App. A.8	Kinematic redundancy
Euler-Lagrange dynamic model	7.1, 7.3, App. B	Lagrangian dynamics
Properties, extensions, and uses of dynamic models	7.2, 7.4, 7.6, 7.7, 7.8	Linear parametrization
Introduction to robot control	8.1, App. C.2, App. C.3	Introduction to robot control
Position regulation in joint space (free motion)	8.2, 8.3 (parts), 8.5 (intro), 8.5.1	Regulation
		Iterative learning
Trajectory tracking in joint space (free motion)	8.5.2, 8.5.3, 8.5.4, 8.7	Trajectory tracking control
		Adaptive trajectory control
Cartesian control (free motion)	8.6	Cartesian control
Interaction modeling and control	All Chap. 9 except: 9.4.3, 9.5.2, 9.7.1	Environment interaction control
		Impedance control
		Hybrid control
Machine learning for robotics	Research papers will be provided	Trajectory learning using DMP
		Introduction to ProMP, state-based learning and reinforcement learning
Visual servoing (kinematic approach)	10.1, 10.2 (parts), 10.3.2, 10.3.3, 10.5 (parts), 10.6, 10.7.2, 10.8.2, 10.9	Visual servoing
Textbook #1: H. J. Marquez, Nonlinear Control Systems: Analysis and Design, Wiley, 2003.		
Textbook #2: J. J. Craig, Introduction to Robotics: Mechanics and Control, Pearson, 4th edition, 2018.		
Textbook #3: B. Siciliano, L. Sciavicco, G. Villani, G. Oriolo, Robotics: Modelling, Planning and Control, Springer, 3rd Edition, 2009.		

UNIVERSITY AND FACULTY POLICIES

COURSE OUTLINE POLICY

The policy about course outlines can be found in Course Requirements, Evaluation Procedures and Grading of the University Calendar, see https://calendar.ualberta.ca/

RESPECT AND PROFESSIONALISM

The Faculty of Engineering is committed to fostering and protecting an equitable, inclusive, and respectful work and study environment in line with University of Alberta policies and professional engineering industry standards. University is an opportunity for students to explore areas of interest and to potentially pursue a career in a specific field. The Faculty of Engineering prepares students to uphold industry standards to become a Professional Engineer (P. Eng). Respect, professionalism, and accountability must be upheld within the Faculty of Engineering.

Harassment and discrimination are serious issues that have a negative effect on culture and therefore the Student Code of Behaviour states that no student shall discriminate against or harass any person or group of persons. The Faculty expects an environment free of harassment, discrimination, and bullying. Please refer to the University's Discrimination, Harassment, and Duty to Accommodate Policy for definitions.

SAFETY DURING LEARNING ACTIVITIES

In all Faculty of Engineering courses, labs, seminars or other learning activities, safety is of paramount importance. In some cases, laboratory work in a program requires high standards for risk management to keep potential hazards safely under control. Anyone found to be unable to function safely, due to intoxication, harassment or discriminatory behaviour, or other reasons, in the class, lab, seminar or other learning activity may be asked to leave or be removed for their and the safety of other participants and instructors in alignment with the Student Code of Behaviour. As members, or prospective members, of the engineering profession, it is your responsibility to identify and inform the proper authorities of an unsafe work/learning environment.

AUDIO/VIDEO RECORDING

Audio or video recording, digital or otherwise, of lectures, labs, seminars or any other teaching environment by students is allowed only with the prior written consent of the instructor or as a part of an approved accommodation plan. Student or instructor content, digital or otherwise, created and/or used within the context of the course is to be used solely for personal study, and is not to be used or distributed for any other purpose without prior written consent from the content author(s).

Only those items specifically authorized by the instructor may be brought into the exam facility. The use of unauthorized personal listening, communication, recording, photographic and/or computational devices is strictly prohibited. Students should refrain from bringing any unauthorized electronic device into an examination room, including cell phones, high tech watches, high tech glasses or other such devices.

Engineering at Alberta

ACADEMIC INTEGRITY

Students at the University of Alberta must read and follow, in its entirety, the

Code of Student Behaviour

Failure to know the code is not an acceptable excuse for breaking the code.

The University of Alberta is committed to the highest standards of academic integrity and honesty. Students are expected to be familiar with these standards regarding academic honesty and to uphold the policies of the University in this respect. Students are particularly urged to familiarize themselves with the provisions of the Code of Student Behaviour (on the University Governance website) and avoid any behaviour which could potentially result in suspicions of cheating, plagiarism, misrepresentation of facts and/or participation in an offence. Academic dishonesty is a serious offence and can result in suspension or expulsion from the University.

Engineering students studying in the province of Alberta should also follow the

Code of Ethics

by The Association of Professional Engineers and Geoscientists of Alberta (APEGA).

The Code of Student Behaviour should not be too hard to follow. Listen to your instructor, be a good person, and do your own work, as this will lead you toward a path to success. Failure to follow the code can result in a grade of 'F' for the course, a transcript remark, suspension, and even expulsion from the university.

"Integrity is doing the right thing, even when no one is watching"
C. S. Lewis

NEED HELP?

24/7 HELP

Empower Me (international)
1-833-628-5589

Edmonton Distress Line
780-482-4357 (HELP)

There are a lot of services available to students on campus and in Edmonton, and sometimes it's hard to know where to go. While this isn't a comprehensive list, the services shown here should at least give you some ideas about where to start. If you're still not sure, check out the services just beneath this box—they'll give you the guidance you're looking for.

DON'T KNOW WHERE TO GO?

Student Service Centre

The U of A's central hub to find the right help for your needs.
uab.ca/ask

WELLNESS

Counselling and Clinical Services

Free, short-term, appointment-based counselling and psychiatric services. Also offers drop-in workshops. Book an initial consultation.
P: 780-492-5205
M, R, F, 8:00am-4:00pm; T, W, 8:00am-7:00pm

Interfaith Chaplains' Association

Get guidance, care, and support, whether or not you identify with a particular faith. Make an appointment.
P: 780-492-0339 │ E: interfaithchaplains@ualberta.ca

The Landing

Offers drop-in support on matters of gender and sexual diversity.
P: 780-492-4949 │ E: thelanding@su.ualberta.ca
M-R, hours vary

Peer Support Centre

Anonymous, confidential help from trained students. By appointment only.
P:780-492-4268 │E: psc@su.ualberta.ca
M-F, 9:00am-8:00pm

Sexual Assault Centre

Free, anonymous, and confidential drop-in counselling.
P: 780-492-9771 │ E: sexualassaultcentre@ualberta.ca
M-F, 9:00am-8:00pm

University Health Centre

An on-campus health clinic that provides medical services to staff, students, and their spouses and children.
P: 780-492-2612 │ E: hws@ualberta.ca
M-F, 8:30am-4:00pm

ACADEMIC

Engineering Student Services
Drop-in, first-come, first-served advising.
E: enggadvising@ualberta.ca

Engineering Student Success Centre
Drop-in tutoring for first-year courses.
E: dessc@ualberta.ca

Academic Success Centre
Many services to maximize your academic success.
E: success@ualberta.ca
M-F, 8:30am-4:30pm

Academic Accommodations
Connects students with disabilities to accommodations.
E: arrec@ualberta.ca
M-F, 8:30am-4:30pm

Office of the Student Ombuds
Call for complex problems and conflict mediation.
P: 780-492-4689 │ E: ombuds@ualberta.ca

FINANCIAL

Student Service Centre
For awards and other funding supports.
uab.ca/ask

Campus Food Bank
Many food support options available.
E: info@campusfoodbank.com

SOCIAL

Unitea
Arrange a time to socialize with a peer.
E: unitea@ualberta.ca

BearsDen
U of A webpage. Find student groups, local events, and volunteer opportunities.

WORRIED ABOUT SOMEONE?

Helping Individuals at Risk (HIAR)

If you're worried about someone because of the things they've been saying or doing, or there's a noticeable change in their behaviour (often in multiple ways), contact HIAR, who will protect your confidentiality and help decide how best to support the person.

780-492-4372
hiarua@ualberta.ca

CONFIDENTIAL SUPPORT

Office of Safe Disclosure and Human Rights

The OSDHR advises confidentially on sensitive issues you may not feel comfortable solving on your own. Contact the OSDHR if you want to get help or to make a report while keeping your privacy.

780-492-7357
osdhr@ualberta.ca