MAE 4345 Introduction to Robotics

Fall 2017

• Instructor

• Teaching Assistant

TBA

• Course Specifics

 MAE 4345-001 Introduction to Robotics T TH 2:00-3:20pm Woolf 210 Web Site: elearn.uta.edu

• Course Content

This course has both theoretical and experimental components. The theoretical portion consists of analyzing the kinematics and dynamics of robots in order to gain insights into their design and control. The experimental portion involves developing a planar robot and controlling it through either the LabVIEW or development software. Theoretical Students will develop the equations of motion and use them to design and control a robotic manipulator. A robotic manipulator can be classified as a multibody system, thus the course provides an introduction to multibody dynamics. Since the robot is a nonlinear system, techniques in nonlinear control are also addressed. The ability to derive the dynamic model of the robot allows one to develop a simulation that can be used to verify candidate control methodologies. This type of simulation will be developed in this course with the aid of commercially available software. The simulation data is used to develop animations of the robot in order to verify the correctness of the dynamic model and the controller. Students will perform the simulated tasks using an actual robot for comparison.

Experimental The experimental component will culminate with the students developing a controller for the tip position of a 2-DOF planar robot, which generates a predefined path. Students will use LabVIEW or the Arduino IDE as an interface to an Arduino board to control the robot. Students can choose which system they want to use to develop their robot. They will develop their robot gradually over the course of the semester through a number of hands-on experiments. The hardware to be used includes a number of sensors and actuators. Students will learn how to interface, acquire, filter and calibrate data from sensors, and then use the sensor data to implement a controller for the state (position) of a motor. You will learn how to implement a real-time controller for the position of the tip of a 2-DOF (2-motors) planar robot.









• Student Learning Outcomes

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

- develop geometric descriptions of the position and orientation of the robot's components
- derive the equations of motion for a robotic manipulator
- model motors and actuators
- formulate a motor control algorithm for the robot
- simulate the motion of the robot
- interpret simulation data in order to animate the robot's motions
- assemble the hardware and software components required to control a robotic manipulator
- code a motor controller
- code an operational space controller for the robot

• Course Materials

- Textbooks and References

- * *Optional (strongly encouraged)*: "Vector Mechanics: A Systematic Approach", Alan Bowling, Third Edition, Aqualan Press, LLC, 2017.
- Software Used
 - * *Autolev* by Online Dynamics, for symbolic manipulation. Basically *Mathematica* for dynamics using syntax resembling *Matlab*. Students should download a demonstration copy of the software from the site www.Autolev.com. A manual for the software can be checked out from the library, however use of the software will be covered extensively in the lectures.
 - * *Matlab* for general computation, dynamic simulation, and animation. It is assumed that student is familiar with this program, but some tutorials will be provided.
 - * LabVIEW or Arduino IDE will be used as the programming interface for the hardware systems.
- 3D Printing Supplies
 - * Students must purchase enough material for the 3D printing of a five link manipulator.
- Major Assignments and Examinations (tentative)

| Exercise 1 | Due September 21 | 2:00pm |
|------------|------------------|-------------|
| Midterm | October 12 | 2:00-3:20pm |
| Exercise 2 | Due October 19 | 2:00pm |
| Exercise 3 | Due November 9 | 2:00pm |
| Exercise 4 | Due December 5 | 2:00pm |
| Final Exam | December 12 | 2:00-4:30pm |

The final exam date and time cannot be changed, except in very extreme cases.

- Exercise 1: Workspace Analysis (3 weeks) In this exercise the students map out the workspace of their robot. They also use 3D printing to build a robot and compare their workspace with the theoretical one. *This* requires some monetary commitment from the student.
- Exercise 2: Sensors (4 weeks) In this exercise students set up the hardware and software so that they can read sensors. Particularly they should learn to read a joint encoder.
- **Exercise 3: Motor Control (3 weeks)** In this exercise students set up the hardware and software required for the model-based control of a single motor in positioning a single link.
- **Exercise 4: 2DOF Manipulator Control** In this exercise students develop joint space and operational space control for a 2DOF, five link, closed chain manipulator. They will compare the theoretically predicted results to the actual results.

• Attendance At The University of Texas at Arlington, taking attendance is not required but attendance is a critical indicator in student success. Each faculty member is free to develop his or her own methods of evaluating students' academic performance, which includes establishing course-specific policies on attendance. As the instructor of this section, I do not record attendance, but it is recommended that students attend class. However, while UT Arlington does not require instructors to take attendance in their courses, the U.S. Department of Education requires that the University have a mechanism in place to mark when Federal Student Aid recipients "begin attendance in a course." UT Arlington instructors will report when students begin attendance in a course as part of the final grading process. Specifically, when assigning a student a grade of F, faculty report the last date a student attended their class based on evidence such as a test, participation in a class project or presentation, or an engagement online via Blackboard. This date is reported to the Department of Education for federal financial aid recipients.

• Grading Policy

- 1. Homework (20%)
- 2. Exercises (40%)
- 3. Midterm exam (20%)
- 4. Final exam (20%)
- Make-up Exams I do not offer make-up exams under any circumstances.

• Expectations for Out-of-Class Study

Beyond the time required to attend each class meeting, students enrolled in this course should expect to spend a minimum of 9 hours per week of their own time in course-related activities, including reading required materials, completing assignments, preparing for exams, etc.

• Homework Policy

Collaboration on homework is encouraged. You may consult outside reference materials, other students, the teaching assistants, and/or the instructor. However, all solutions that are handed in should reflect your understanding of the subject matter at the time of writing. Late homeworks will not be accepted.

• Grade Grievances

Objections concerning the grading of homeworks and tests should be raised within one week after they are returned. After one week the grade is permanent. Questions about homework grading should be discussed with the TA first. If the problem cannot be resolved with the TA, then it can be brought to my attention.

- Code of Conduct
 - No persistent talking during lecture.
 - No newspaper reading during lecture.
 - No laptops open during lecture unless specifically requested by instructor.
- **Drop Policy** Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. Students will not be automatically dropped for non-attendance. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdraw-ing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).
- **Disability Accomodations** UT Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including The Americans with Disabilities Act (ADA), The Americans with Disabilities Amendments Act (ADAA), and Section 504 of the Rehabilitation Act. All instructors at UT Arlington are required by law to provide reasonable accommodations to students with disabilities, so as not to discriminate on the basis of disability. Students are responsible for providing the instructor with official

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notification in the form of a letter certified by the Office for Students with Disabilities (OSD). Only those students who have officially documented a need for an accommodation will have their request honored. Students experiencing a range of conditions (Physical, Learning, Chronic Health, Mental Health, and Sensory) that may cause diminished academic performance or other barriers to learning may seek services and/or accommodations by contacting:

The Office for Students with Disabilities, (OSD) www.uta.edu/disability or calling 817-272-3364. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability.

Counseling and Psychological Services, (CAPS) www.uta.edu/caps/ or calling 817-272-3671 is also available to all students to help increase their understanding of personal issues, address mental and behavioral health problems and make positive changes in their lives.

- Non-Discrimination Policy The University of Texas at Arlington does not discriminate on the basis of race, color, national origin, religion, age, gender, sexual orientation, disabilities, genetic information, and/or veteran status in its educational programs or activities it operates. For more information, visit uta.edu/eos.
- **Title IX Policy** The University of Texas at Arlington (University) is committed to maintaining a learning and working environment that is free from discrimination based on sex in accordance with Title IX of the Higher Education Amendments of 1972 (Title IX), which prohibits discrimination on the basis of sex in educational programs or activities; Title VII of the Civil Rights Act of 1964 (Title VII), which prohibits sex discrimination in employment; and the Campus Sexual Violence Elimination Act (SaVE Act). Sexual misconduct is a form of sex discrimination and will not be tolerated. For information regarding Title IX, visit www.uta.edu/titleIX or contact Ms. Jean Hood, Vice President and Title IX Coordinator at (817) 272-7091 or jmhood@uta.edu.
- Academic Integrity Students enrolled all UT Arlington courses are expected to adhere to the UT Arlington Honor Code:

I pledge, on my honor, to uphold UT Arlingtons tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.

I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.

UT Arlington faculty members may employ the Honor Code in their courses by having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System Regents Rule 50101, 2.2, suspected violations of universitys standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the students suspension or expulsion from the University. Additional information is available at https://www.uta.edu/conduct/.

- Electronic Communication UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs-/email/mavmail.php.
- **Campus Carry** Effective August 1, 2016, the Campus Carry law (Senate Bill 11) allows those licensed individuals to carry a concealed handgun in buildings on public university campuses, except in locations the University establishes as prohibited. Under the new law, openly carrying handguns is not allowed on college campuses. For more information, visit http://www.uta.edu/news/info/campus-carry/
- Student Feedback Survey At the end of each term, students enrolled in face-to-face and online classes categorized as lecture, seminar, or laboratory are directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each students feedback via the SFS database is aggregated with that of other students enrolled in the course. Students anonymity will be protected to the extent that the law

allows. UT Arlingtons effort to solicit, gather, tabulate, and publish student feedback is required by state law and aggregate results are posted online. Data from SFS is also used for faculty and program evaluations. For more information, visit http://www.uta.edu/sfs.

- Final Review Week for semester-long courses, a period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week unless specified in the class syllabus. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.
- Emergency Exit Procedures Should we experience an emergency event that requires us to vacate the building, students should exit the room and move toward the nearest exit. When exiting the building during an emergency, one should never take an elevator but should use the stairwells. Faculty members and instructional staff will assist students in selecting the safest route for evacuation and will make arrangements to assist individuals with disabilities.
- Student Support Services UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at http://www.uta.edu/universitycollege/resources/index.php.

• Course Schedule

| Lecture | | Material | Assign | Due | |
|---------|---------|--|---------------|-----------|-----------|
| Η | Aug. 24 | Introduction | Ch. 1, 2, 7 | | |
| Т | Aug. 29 | Position and Orientation | | | |
| Н | Aug. 31 | Position and Orientation, (LAB: Workspace) | | HW1, EX1 | |
| Т | Sep. 5 | Position and Orientation | | | |
| Η | Sep. 7 | Constraints | | HW2 | HW1 |
| Т | Sep. 12 | Constraints | | | |
| Η | Sep. 14 | Velocity | Ch. 3, 8 | HW3 | HW2 |
| Т | Sep. 19 | Velocity | | | |
| Η | Sep. 21 | Velocity, (LAB: Sensors) | | HW4, EX2 | HW3, EX1 |
| Т | Sep. 26 | Acceleration | | | |
| Η | Sep. 28 | Mass and Inertia | Ch. 4, 9 | HW5 | HW4 |
| Т | Oct. 3 | Mass and Inertia | | | |
| Η | Oct. 5 | Forces and Moments | Ch. 5, 10 | | HW5 |
| Т | Oct. 10 | Forces and Moments | | | |
| Η | Oct. 12 | Midterm | | HW6 | |
| Т | Oct. 17 | Equations of Motion | Ch. 6, 11 | | |
| Η | Oct. 19 | Equations of Motion, (LAB: One-Link Arm) | | HW7, EX3 | HW6, EX2 |
| Т | Oct. 24 | Equations of Motion | | | |
| Η | Oct. 26 | Simulation and Animation | | HW8 | HW7 |
| Т | Oct. 31 | Model-based control | | | |
| Η | Nov. 2 | Joint Space Control | | HW9 | HW8 |
| Т | Nov. 7 | Joint Space Control | | | |
| Η | Nov. 9 | Trajectory Generation | | HW10, EX4 | HW9, EX3 |
| Т | Nov. 14 | Operational Space Control | | | |
| Η | Nov. 16 | Operational Space Control | | HW11 | HW10 |
| Т | Nov. 21 | Motor Sizing | | | |
| Η | Nov. 23 | Thanskgiving | | | |
| Т | Nov. 28 | Mobile Robots | | HW12 | HW11 |
| Η | Nov. 30 | Mobile Robots | | | |
| Т | Dec. 5 | Mobile Robots | | | HW12, EX4 |
| Т | Dec. 12 | Final Exam 2-4:30pm | Comprehensive | | |

As the instructor for this course, I reserve the right to adjust this schedule in any way that serves the educational needs of the students enrolled in this course. **This schedule is subject to change without notice.** - Alan P. Bowling