

# ***MECH/EECS/BMEN 6324: Robot Control***

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## **Course Information**

**Fall 2016**

**Class Meeting:** M/W 5:30-6:45p

**Starts:** August 22, 2016

**Ends:** December 15, 2016

**Location:** ECSN 2.112

**Instructor:** Dr. Robert D. Gregg

**Office:** ECSN 3.202

**Phone:** 972-883-4657

**Email:** rgregg@utdallas.edu

**Office Hours:** Mondays, 11:00a-12:00p or by appointment

**Teaching Assistant:** Kyle Embry

**Office:** ATC 2.901

**Email:** kre140030@utdallas.edu

**Office Hours:** Thursdays 4-5p

## **Course Pre-requisites, Co-requisites, and/or Other Restrictions**

*An Introduction to Control Theory at the level of MECH 6300 is necessary. Knowledge of linear algebra and differential equations is also required; Knowledge of Matlab and Mathematica is desirable.*

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## **Course Description**

**MECH/EECS/BMEN 6324 - Robot Control** (3 semester hours) Dynamics of robots; methods of control; force control; robust and adaptive control; feedback linearization; Lyapunov design methods; passivity and network control; control of multiple and redundant robots; teleoperation. Prerequisite: MECH 6300. (3-0) T

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## **Student Learning Objectives/Outcomes**

*Upon successful completion of this course, students will:*

- 1. have a basic understanding of the kinematics of robot manipulators and mobile robots.*
- 2. understand the dynamics of Lagrangian mechanical systems and be able to compute the dynamic equations of motion of any robot manipulator.*
- 3. have a basic understanding of nonlinear control methods such as feedback linearization, passivity-based, robust, and adaptive control, and be able to analyze the stability and tracking performance of closed loop systems using Lyapunov theory.*
- 4. be able to model, design, and simulate nonlinear controllers for manipulators and mobile robots.*

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## Required Textbooks and Materials

- (MLS) *R. Murray, Z. Li, and S. Sastry, A Mathematical Introduction to Robotic Manipulation, CRC Press, Boca Raton, FL, 1994.*  
Free download: <http://www.cds.caltech.edu/~murray/books/MLS/pdf/mls94-complete.pdf>
- (SHV) *Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, Robot Modeling and Control, John Wiley & Sons, Inc., New York, NY, 2006.*

## Required Software

### MathWorks MATLAB

Access/installation: <http://www.utdallas.edu/ir/howto/matlab/>

### Wolfram Mathematica

Access/installation: <http://www.utdallas.edu/ir/howto/mathematica/>

Tutorials: <http://www.wolfram.com/broadcast/screencasts/hands-on-start/>

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## Exams and Grading Policy

*There will be homework assignments involving worked problems and computer simulations, a midterm exam, and a final exam. Grades will be determined based on the following formula:*

*Homework 25%*

*Midterm Exam 25%*

*Final Exam 40%*

*Class Participation 10%*

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## Topical Outline

1. *Screw Theory for Kinematics (MLS)*
  - *Rotation Matrices and Homogeneous Transformations*
  - *Exponential Coordinates for Rigid Motion*
  - *Twists and Wrenches*
  - *Forward and Inverse Kinematics*
  - *The Manipulator Jacobian*
2. *Dynamics (MLS/SHV)*
  - *The Euler-Lagrange Equations*
  - *The Dynamics of Example Manipulators*
  - *Properties of Manipulator Dynamic Equations*
3. *Independent Joint Control (SHV)*
  - *Actuator Dynamics*
  - *Set-Point Control*
  - *Feedforward Control*
  - *Drive-Train Dynamics*
  - *State Space Design*

4. *Multivariable Nonlinear Control (SHV)*
  - *Lyapunov Stability and the Invariance Principle*
  - *PD Control*
  - *Inverse Dynamics*
  - *Passivity-Based Robust and Adaptive Control*
  - *Force Control*
  - *Energy Shaping*
5. *Geometric Nonlinear Control (SHV)*
  - *Vector Fields and Distributions*
  - *The Frobenius Theorem*
  - *Feedback Linearization*
6. *Introduction to Mobile Robots (SHV)\**
  - *Nonholonomic Constraints*
  - *Kinematics and Dynamics of Mobile Robots*
  - *Motion Planning and Obstacle Avoidance*
  - *Controllability and Chow's Theorem*
  - *Controller Design for Mobile Robots*

\* if time permits

## Technical Support

If you experience any problems with your UTD account you may send an email to: [assist@utdallas.edu](mailto:assist@utdallas.edu) or call the UTD Computer Helpdesk at 972-883-2911.

## Course Policies

<b>Homework</b>	Homework will be assigned and graded. <b>Homework is due within the first 10 minutes of class on the due date, otherwise it is considered late.</b> On the day that homework is due, a short quiz may be given that is heavily based on the homework, which will count as extra credit towards the homework grade.
<b>Make-up Exams</b>	<b>No make-up exams will be given.</b> In the event of an excused absence (illness, job-related travel, holy day absence, etc.; Proper documents should be provided), the weight of the exam will be shifted to the remaining exams.
<b>Late Work</b>	<b>Not acceptable</b>
<b>Class Attendance</b>	Class attendance and participation will count toward 10% of the course grade.
<b>Classroom Citizenship</b>	Professional at all times. Smelly foods are distracting to others and will not be allowed in the classroom. As courtesy to classmates and instructor, electronic devices should be turned off during class, except when permitted by the instructor. <b>Cell phone use (e.g., texting) is disruptive to class and will not be tolerated. Laptop use is not permitted during lecture except for scheduled in-class exercises.</b>
<b>Email Use</b>	The University of Texas at Dallas recognizes the value and efficiency of

	<p>communication between faculty/staff and students through electronic mail. At the same time, email raises some issues concerning security and the identity of each individual in an email exchange. The university encourages all official student email correspondence be sent only to a student's U.T. Dallas email address and that faculty and staff consider email from students official only if it originates from a UTD student account. This allows the university to maintain a high degree of confidence in the identity of all individual corresponding and the security of the transmitted information. UTD furnishes each student with a free email account that is to be used in all communication with university personnel. The Department of Information Resources at U.T. Dallas provides a method for students to have their U.T. Dallas mail forwarded to other accounts. <b>Per FERPA policy, grades cannot be discussed via email.</b></p>
<b>Student Conduct and Discipline</b>	<p>The University of Texas System and The University of Texas at Dallas have rules and regulations for the orderly and efficient conduct of their business. It is the responsibility of each student and each student organization to be knowledgeable about the rules and regulations which govern student conduct and activities. General information on student conduct and discipline is contained in the UTD publication, <i>A to Z Guide</i>, which is provided to all registered students each academic year.</p> <p>The University of Texas at Dallas administers student discipline within the procedures of recognized and established due process. Procedures are defined and described in the <i>Rules and Regulations, Board of Regents, The University of Texas System, Part 1, Chapter VI, Section 3</i>, and in Title V, Rules on Student Services and Activities of the university's <i>Handbook of Operating Procedures</i>. Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations (SU 1.602, 972/883-6391).</p> <p>A student at the university neither loses the rights nor escapes the responsibilities of citizenship. He or she is expected to obey federal, state, and local laws as well as the Regents' Rules, university regulations, and administrative rules. Students are subject to discipline for violating the standards of conduct whether such conduct takes place on or off campus, or whether civil or criminal penalties are also imposed for such conduct.</p>
<b>Academic Integrity</b>	<p>The faculty expects from its students a high level of responsibility and academic honesty. Because the value of an academic degree depends upon the absolute integrity of the work done by the student for that degree, it is imperative that a student demonstrate a high standard of individual honor in his or her scholastic work.</p> <p>Scholastic dishonesty includes, but is not limited to, statements, acts or omissions related to applications for enrollment or the award of a degree, and/or the submission as one's own work or material that is not one's own. As a general rule, scholastic dishonesty involves one of the following acts: cheating, plagiarism, collusion and/or falsifying academic records. Students suspected of academic dishonesty are subject to disciplinary proceedings.</p> <p><b>I take this very seriously. Any case of suspected cheating or plagiarizing will be referred to Judicial Affairs.</b></p>
<b>Withdrawal from Class</b>	<p>The administration of this institution has set deadlines for withdrawal of any college-level courses. These dates and times are published in that semester's course catalog. Administration procedures must be followed. It is the student's responsibility to handle withdrawal requirements from any class. In other words, I cannot drop or withdraw any student. You must do the proper paperwork to ensure that you will not receive a final grade of "F" in a course if you choose not to attend the class once you are enrolled.</p>

<p><b>Student Grievance Procedures</b></p>	<p>Procedures for student grievances are found in Title V, Rules on Student Services and Activities, of the university's <i>Handbook of Operating Procedures</i>.</p> <p>In attempting to resolve any student grievance regarding grades, evaluations, or other fulfillments of academic responsibility, it is the obligation of the student first to make a serious effort to resolve the matter with the instructor, supervisor, administrator, or committee with whom the grievance originates (hereafter called "the respondent"). Individual faculty members retain primary responsibility for assigning grades and evaluations. If the matter cannot be resolved at that level, the grievance must be submitted in writing to the respondent with a copy of the respondent's School Dean. If the matter is not resolved by the written response provided by the respondent, the student may submit a written appeal to the School Dean. If the grievance is not resolved by the School Dean's decision, the student may make a written appeal to the Dean of Graduate or Undergraduate Education, and the dean will appoint and convene an Academic Appeals Panel. The decision of the Academic Appeals Panel is final. The results of the academic appeals process will be distributed to all involved parties.</p> <p>Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations.</p>
<p><b>Incomplete Grades</b></p>	<p>As per university policy, incomplete grades will be granted only for work unavoidably missed at the semester's end and only if 70% of the course work has been completed. An incomplete grade must be resolved within eight (8) weeks from the first day of the subsequent long semester. If the required work to complete the course and to remove the incomplete grade is not submitted by the specified deadline, the incomplete grade is changed automatically to a grade of <b>F</b>.</p>
<p><b>Disability Services</b></p>	<p>The goal of Disability Services is to provide students with disabilities educational opportunities equal to those of their non-disabled peers. Disability Services is located in room 1.610 in the Student Union. Office hours are Monday and Thursday, 8:30 a.m. to 6:30 p.m.; Tuesday and Wednesday, 8:30 a.m. to 7:30 p.m.; and Friday, 8:30 a.m. to 5:30 p.m.</p> <p style="text-align: center;">The contact information for the Office of Disability Services is:  The University of Texas at Dallas, SU 22  PO Box 830688  Richardson, Texas 75083-0688  (972) 883-2098 (voice or TTY)</p> <p>Essentially, the law requires that colleges and universities make those reasonable adjustments necessary to eliminate discrimination on the basis of disability. For example, it may be necessary to remove classroom prohibitions against tape recorders or animals (in the case of dog guides) for students who are blind. Occasionally an assignment requirement may be substituted (for example, a research paper versus an oral presentation for a student who is hearing impaired). Classes enrolled students with mobility impairments may have to be rescheduled in accessible facilities. The college or university may need to provide special services such as registration, note-taking, or mobility assistance.</p> <p>It is the student's responsibility to notify his or her professors of the need for such an accommodation. Disability Services provides students with letters to present to faculty members to verify that the student has a disability and needs accommodations. Individuals requiring special accommodation should contact the professor after class or during office hours.</p>

<p><b>Religious Holy Days</b></p>	<p>The University of Texas at Dallas will excuse a student from class or other required activities for the travel to and observance of a religious holy day for a religion whose places of worship are exempt from property tax under Section 11.20, Tax Code, Texas Code Annotated.</p> <p>The student is encouraged to notify the instructor or activity sponsor as soon as possible regarding the absence, preferably in advance of the assignment. The student, so excused, will be allowed to take the exam or complete the assignment within a reasonable time after the absence: a period equal to the length of the absence, up to a maximum of one week. A student who notifies the instructor and completes any missed exam or assignment may not be penalized for the absence. A student who fails to complete the exam or assignment within the prescribed period may receive a failing grade for that exam or assignment.</p> <p>If a student or an instructor disagrees about the nature of the absence [i.e., for the purpose of observing a religious holy day] or if there is similar disagreement about whether the student has been given a reasonable time to complete any missed assignments or examinations, either the student or the instructor may request a ruling from the chief executive officer of the institution, or his or her designee. The chief executive officer or designee must take into account the legislative intent of TEC 51.911(b), and the student and instructor will abide by the decision of the chief executive officer or designee.</p>
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*These descriptions and timelines are subject to change at the discretion of the Professor.*