ME/RBE 501 – Robot Dynamics

Syllabus (Spring Semester - 2011)

Introduction

Professor	Gregory Fischer, PhD gfischer@wpi.edu Higgins Lab 206 508-831-5261 http://www.wpi.edu/~gfischer http://aimlab.wpi.edu/AIM-lab/index.php/Gregory_Fischer				
Lectures	Tuesdays, 6:00-8:50 pm in AK 232				
Labs	No assigned lab session				
Office Hours	**Mon**	**Tue**	**Wed**	**Thursday**	**Friday**
	3-4pm				11-12pm
	Or By Appointment ***(please email me to set up a time)***				
Course URL	Course material will be posted on the *myWPI* site				
Required Primary Textbook	*Robot Modeling and Control,* M. Spong, S. Hutchinson, M. Vidyasagar, Wiley, 2005. (one copy on reserve in library)				
Additional Recommended Textbooks and References	1. *Springer Handbook of Robotics,* B. Siciliano, O. Khatib (eds.), Springer, 2008. (pdf available free online through library) 2. *Theory of Applied Robotics 2nd Ed.,* R. Jazar, Springer, 2010. (electronic version available free online through library) 3. *A Mathematical Introduction to Robotic Manipulation*, Richard M. Murray, Zexiang Li and S. Shankar Sastry. (on reserve in library) (available free online at: http://www.cds.caltech.edu/~murray/mlswiki) 4. *Introduction to Robotics: Mechanics & Control,* 3ed, J. Craig, Prentice Hall, 2004. (on reserve in library) 5. *Fundamentals of Robotics: Analysis and Control*, Robert J. Schilling, Prentice Hall, 1990. (on reserve in library) 6. *Introduction to Autonomous Mobile Robots*, Roland Siegwart and Illah Nourbakhsh (electronic version available free online through library)				

Description

Foundations and principles of robotic manipulation. Topics include computational models of objects and motion, the mechanics of robotic manipulators, the structure of manipulator control systems, planning and programming of robot actions. The focus of this class is on the kinematics and programming of robotic mechanisms. Important topics also include the dynamics, control, sensor and effector design, and automatic planning methods for robots. The fundamental techniques apply to arms, mobile robots, active sensor platforms, and all other computer-controlled kinematic linkages. The primary applications include robotic arms and mobile robots and lab projects would involve programming of representative robots. An end of term team project would allow students to program robots to participate in challenges or competitions.

Recommended background: RBE 500 or equivalent

Course Objectives

Upon completion of this course, students will be able to:

1. Understand coordinate systems and representations in 3D space
2. Understand representations of rotations and coordinate transformations
3. Analyze the position and velocity kinematics of robot arms
4. Analyze force propagation through linkages
5. Develop dynamic models for robot arms
6. Develop robot control strategies
7. Calibrate robotics systems
8. Perform path and motion planning
9. Develop simulations of robotic systems
10. Critically analyze and report on robotics literature
11. Apply concepts to a comprehensive hands-on project

Ground Rules

1. *The instructor reserves the right to modify the course outline and policies mentioned in this syllabus at any time during the term.*
2. **Homework and Quizzes:** Homework will be assigned regularly throughout the term. All homework will have a due date and no late homework will be accepted. Selected homework problems will be graded for credit. Announced and unannounced quizzes may be given during the term. Additional assignments, such as in-class literature reviews, will be counted as homework. Homework, quizzes and other in class assignments are worth 30% of the total score in the course. Homework is to be turned in at the beginning of class on the date due. Late assignments will be docked 15% per day late and will not be accepted more than 3 days late.
3. **Exams:** Two exams will be given as shown on the course schedule. Make-ups will only be granted to the students who have an acceptable excuse approved in advance. Each exam is worth 20% of the total score.
4. **Projects:** Students will form teams of two (or three if necessary) for the course project. Project proposal and interim reports will be assigned during the course of the term. The overall project grade will make up 30% of the total score and will include the proposal, interim reports, final report, presentation and demonstration.
5. **Grading:** You must complete the final project and you must take all the exams to receive a passing grade in the course. You are expected to complete all homework and other assignments and quizzes.

Homework and Quizzes	30%
Exams	40%
Project	30%
Total	**100%**

6. **Attendance and participation:** Class attendance, active participation and interaction are mandatory. You will be responsible for all class material, not all notes will be available online. We will also have in-class assignments, presentations, and discussions.

7. **Calculator Policy:** Only models of calculators approved by The National Council of Examiners for Engineering and Surveying (NCEES) are permitted in the exams. You are responsible for bringing an approved calculator to exams, others will not be allowed.

   For more information: http://www.ncees.org/Exams/Calculator_policy.php

8. **Academic Honesty:** Collaboration is allowable an encouraged. However, please review the following guideline to avoid crossing the boundary from "helping" to "cheating"

   Any work you present as your own should represent your understanding of the material. Following are examples of acceptable and unacceptable actions under this policy.
   Exams
   Acceptable:
   - Looking at allowable materials (TBD)
   - Using calculator (as specified in course policies) or other digital assistant to perform numerical calculations.

   Unacceptable:
   - Using calculator or other digital assistant to access stored formulas or notes, perform calculations beyond the capabilities of the listed acceptable devices, or to access any other resource or collaboration during exam.
   - You are not to use computer software for the exams.

   Homework
   Acceptable:
   - Discussing a homework problem with someone else to gain a better understanding.
   - Looking at a similar problem from solutions of previous problem sets to get an idea of how to approach the problem.
   - Computer software is allowable (and in many cases encouraged) when specified by the instructor, however even when using the computer you are responsible for having your own understanding of the calculations being performed.

   Unacceptable
   - Copying material from someone else's solution and handing it in as your own.
   - Copying a solution from any other source and handing it in as your own.

   Please review WPI's Academic Honesty Policies on the web:
   http://www.wpi.edu/Pubs/Policies/Honesty/policy.html

9. **Student Disability Services:** If you need course adaptations or accommodations because of a disability, or if you have medical information to share with me, please make an appointment with Prof. Padir by Friday, October 31, 2008. His office location and hours are listed in this syllabus and online. If you have not already done so, students with disabilities, who believe that they may need accommodations in this class, are encouraged to contact the Disability Services Office (DSO), as soon as possible to ensure that such accommodations are implemented in a timely fashion. The DSO is located in Daniels Hall, (508) 831-5235.

10. Students are encouraged to use campus support services, which include the:
    - Academic Resources Center
    - Writing Center
    - M*A*S*H (Math and Science Help)

Tentative Schedule of RBE501 – S'11

Class #	Date	Topic (Tentative, subject to change)	Readings (See myWPI site for additional references)	Assignment Due (Dates subject to change)
1	18-Jan	Course Introduction Notation and mathematical background Rigid motions and coordinate transformations Representations of rotations	Spong, Ch 1-2 Murray, Ch 2.1-2.3	
2	25-Jan	Manipulator forward kinematics Composite transformations D-H parameters	Spong, Ch 3.1-2 Murray, Ch 3.1-3.2	
3	1-Feb	Velocity/Differential kinematics Derivation of manipulator Jacobian	Spong, Ch 4 Murray, Ch 3.4	HW#1 Due
4	8-Feb	Mobile robot kinematics Pfaffian constraints, Nonholonomic systems	Siegwart, Ch 3 Murray, Ch 6.1,7.3-7.4	
5	15-Feb	Manipulability Inverse kinematics Closed form solutions Newton –Euler approach	Spong, Ch 3.3, 4.12 Murray, Ch 3.3	Project Proposal Due
6	22-Feb	Force/torque relationships Force propagation, wrenches Manipulator stiffness and force control	Spong, Ch 4.10, 9 Murray, Ch 3.3	HW#2 Due
7	1-Mar	**Midterm Exam** (6:00-7:30pm) Newtonian mechanics Dynamic systems		
	8-Mar	*No Class – Spring Break*		
8	15-Mar	Manipulator dynamics Euler-Lagrange equations Energy-based techniques Equations of motion	Spong, Ch 7 Murray, Ch 4.1-3	Project Progress Report Due
9	22-Mar	Continued manipulator dynamics Newton-Euler formulation Vehicle dynamics & Nonholonomic motion planning	Murray, Ch 8.1-3	HW#3 Due
10	29-Mar	Independent joint control Motion control Computer torque control	Spong, Ch 8 Murray, Ch 4.4-6	
11	5-Apr	Robot calibration Assessment of precision, accuracy, repeatability Registration, Least squares Vision systems and tracking	Spong, Ch 11, 12	HW#4 Due
12	12-Apr	Path and task planning Motion planning Redundancy resolution	Spong, Ch 5	
13	19-Apr	*No Class – Passover*		HW#5 Due
14	26-Apr	Final project presentations **Distribute Take-home Final Exam**		
		Final Assignments Due		Final Due Fri. 4/29 Report Due Mon. 5/3

Updated: *Thursday, January 06, 2011*