UNIVERSITY of HOUSTON | ECE

ECE 5397/6397: Introduction to Robotics
Spring 2016

Location: D3 W205
Class: 11:30am-1:00pm, Tues & Thurs in D3 W205, 01/19/2016 - 05/13/2016
Office hours: 2:00-3:00pm, Tues & Thurs in N386, or by appointment
Instructor: Dr. Aaron T. Becker, email: atbecker@uh.edu, phone: (713) 743-6671
Teaching Assistant: Li Huang email: lihuang.mech@gmail.com, phone: (713) 743-7296

Course Description: Fundamentals of robotics including *rigid motions*; *homogeneous transformations*; *forward* and *inverse kinematics*; *velocity kinematics*; *motion planning*; *trajectory generation*; *sensing*, *vision*; *control*. Also, introduction to *swarm programming*, *search strategies*, and *distributed planning* and *control.*

Project 1, Swarmathon: The University of Houston was selected as a finalist for the NASA Swarmathon Challenge, http://nasaswarmathon.com/. As a finalist, we have been awarded three 'swarmie' robots, as well as access to a simulator environment in ROS for testing algorithms. Students will form 2-person teams. Each team will complete three challenges in ROS, concluding with an in-class competition on the Swarmathon challenge. Winning teams will be allowed to implement on the hardware robots and will compete in the national competition. **Before class begins**, please complete the introductory modules at http://nasaswarmathon.com/outreach/ and install ROS, http://www.ros.org/, on your computer.

Project 2, Robot Arm: Students will form 2-person teams. Each team will build and control their own robot arm, powered by servos. The instructor will provide standard laser-cut arm components; teams will purchase their own servos & Arduino Mega (or suitable clone). We will use these arms to implement automatic controllers, forward and inverse kinematics, and forward/inverse velocity control. Teams may design their own laser-cut components for the final stage of the project.

Prerequisites:
Credit for or *concurrent enrollment* in (MATH 3321 **or {**Alternative: Credit for or *concurrent enrollment* in Calculus III (MATH 2433), Linear Algebra (Math 2331), Differential Equations (MATH 3331)**}**, **and {**Automatic Controls (ECE 4375) **or** Dynamics and Control of Mechanical Systems (MECE 3338)**}**

Textbook: Robot Modeling and Control
Mark W. Spong, Seth Hutchinson, M. Vidyasagar,
John Wiley and Sons, Inc., 2005
Readings and assignments will come from this book. You may share a book with a classmate. Over the next 14 weeks we will intensively learn from chapters 1, 2, 3, 4, 5, 11, 12.

Grading: Grades will be determined on the basis of exams, quizzes, attendance, and submitted homework grades with the following **approximate** weights. The actual weights will be fixed at the end of the semester.

- 30% Homework
- 20% Lab
- 25% Exam 1
- 25% Exam 2
- You are allowed to discuss the homework problems and projects with your classmate but you cannot copy your classmate's homework and project.
- Suspected cases of dishonesty will be promptly submitted to department's hearing officer, as per the University of Houston's Academic Honesty policy.

Exam Schedule: The FINAL EXAM will be given on Tues., May 10 from 11:00 am-2:00 pm,

Late Policy: Paper copies of your homework are due by 11:35am. A homework drop box will be physically locked after that time, and we will discuss the answers.

Goals: By the course end, you will be able to implement and use:
Coordinate transforms, rotation matrices, Denavit-Hartenberg convention, Robotics kinematics and inverse kinematics, velocity kinematics and inverse velocity kinematics, basic computer vision, path planning artificial potential fields, sampling-based methods. A lab component will integrate these topics with robotic hardware.

Note: Reading assignments should be completed *before* the lecture for which they are assigned.

Date	Topic	Assignments
Jan 19	General introduction and overview of the course	Read Chap. 1, student registration swarmathon
Jan 21	Rotation matrices, SO(n)	Read 2.1, 2.2, http://nasaswarmathon.com/outreach/
Jan 22	Webinar – Student Orientation / Hardware	http://nasaswarmathon.com/timeline/
Jan 26	Coordinate transformations, composition of rotations, homogeneous transformations	Read 2.3, 2.4, 2.7
Jan 28	Coordinate transformation examples, Parameterizations of SO(3), Euler angles	Read 2.5, github checkin #1
Feb 2	Similarity transformations, rotations w.r.t. the fixed frame, axis/angle representation Introduction to forward kinematics	Read 3.1 and 3.2
Feb 4	Forward kinematics: Denavit-Hartenberg convention and the derivation of D-H transformation matrix, assigning link frames using the DH convention.	
Feb 9	Forward kinematics examples	
Feb 11	Inverse kinematics: general overview, geometric method, kinematic decoupling	Read 3.3
Feb 16	Inverse kinematics examples: Articulated arm, SCARA arm, and spherical wrist.	
Feb 18	Introduction to angular velocity, skew symmetric matrices	Read 4.1-4.3
Feb 23	so(3) and the derivative of a rotation matrix, velocity of a point attached to a moving frame, addition of angular velocities	Read 4.4-4.6
Feb 25	The manipulator Jacobian	
Mar 1	Jacobian examples	
Mar 3	Manipulator singularities	Read 4.9
Mar 8	Computer vision overview, segmentation	Read 11.3
Mar 10	Segmentation by minimizing within-group variance, recursive formulation for within-group variance	Read 11.3
Mar 15	SPRING BREAK	
Mar 17	SPRING BREAK	
Mar 22	Connected components, moments	Read 11.4-11.5
Mar 24	Position and orientation in binary images	
Mar 29	Imaging geometry	Read 11.1-11.2
Mar 31	Exam 1	
Apr 5	Camera calibration	Visual servo control Chapter 12
Apr 7	Introduction to path planning: configuration space obstacles for polygons that translate in the plane, generalized Vornoi graphs, visibility graphs, cell decomposition.	Read 5.1
Apr 12	Path planning using artificial potential fields	Read 5.2
Apr 14	Path planning using artificial potential fields (cont), planning as optimization	Read 5.3
Apr 18-22	Swarmathon at NASA Kennedy Space Center	
Apr 19	Sampling-based methods for path planning	Read 5.4
Apr 21	Inverse Velocity , projection onto the null space of the manipulator Jacobian	Read 4.11

Apr 26	Singular value decomposition, Manipulability	Read 4.12 & Appendix B
Apr 28	Manipulability, gradient projection to achieve secondary tasks.	

Academic Honesty Policy: Students in this course are expected to follow the *Academic Honesty Policy* of the University of Houston. It is your responsibility to know and follow this policy. You must sign the Academic Honesty Statement on the last page of this handout, detach it, and submit it. If you fail to do this, you may be dropped from the course. For more information, see the *Academic Honesty* in the *Undergraduate Catalog* which is available on-line at http://catalog.uh.edu/content.php?catoid=8&navoid=1352

Religious Holy Days: Students whose religious beliefs prohibit class attendance on designated dates or attendance at scheduled exams may request an excused absence. To do this, you are **strongly encouraged** to request the excused absence, in writing, by Wednesday, February 3, 2015. Please submit this written request to your instructor to allow the instructor to make appropriate arrangements.
More information can be found at
http://www.uh.edu/dos/studenthandbook/academicpolicy/a_holydays.html

Students with Disabilities: Students with recognized disabilities will be provided reasonable accommodations, appropriate to the course, upon documentation of the disability with a *Student Accommodation Form* from the *Center for Students with Disabilities*. To receive these accommodations, you must request the specific accommodations, by submitting them to the instructor in writing, by Wednesday, February 3, 2015. Students who fail to submit a written request will not be considered for accommodations. More information, can be found at
http://www.uh.edu/dos/studenthandbook/academicpolicy/a_disability.html

Attendance: Attendance at all classes is expected and required. The instructor may, if he chooses, take attendance in any class, at any time during the class. The instructor may do this as many times per class period as he chooses, without warning. The attendance grade can be included in the grade for the course. Attendance at every class is expected. Roll will be occasionally taken and an in-class exam may be given during any class period. There will be no make-up of missed in-class exams.

Grade Posting: You may find out your grade in the course online using PeopleSoft. Normally, the grades are available about one week after the final exam. The instructor is not allowed to give out grades over the phone or by email. During the semester, grades will be posted on Blackboard in a secure manner, i.e., so that only you will have access to your grades. Final grades will also be posted on Blackboard at the end of the semester; however, the official grade reporting is done on PeopleSoft, not on the Blackboard.

Grade Point Rule: The following **approximate** grade point scale will be used in determining your grade. This scale may be modified somewhat, but is included here so that you will have a general idea of how well you are doing in the course. The final grade scale will be determined at the end of the semester.

90–100: A's 80–89.9: B's 70–79.9: C's 60–69.9: D's <60: F

Withdrawal Policy: The withdrawal dates listed in the Academic Calendar section of the *Class Schedule* will be followed strictly. You may drop the course without receiving a grade until Wednesday, February 4, 2015 which is the University's last day to drop without receiving a grade. After this date and until Monday April 6, which is the University's last day to drop, you may drop with a W if you have not exceeded your total W limit (the limit applies to undergraduate students only). Grades of Incomplete (I) will be given only when a small portion of the course has not been completed for a good reason. If the material has been completed, an "I" grade cannot be given. Detailed information about these issues is available in the University of Houston Undergraduate Catalog.

Blackboard: We will be using the Blackboard Learn web site (http://www.uh.edu/blackboard) for posting of grades and email only. All documents and handouts will be available on the website at http://www.egr.uh.edu/courses/ece/Ece2300/. We will assume that your UH email alias (joejones@uh.edu) is pointed to a working email server, and that you are available at that address.

Related Robotics Courses:
Consider taking MECE 3400 "Introduction to Mechanics" ,
COSC 4332 or 6332 - Medical Robots & Interventions, INDE 7361 - Industrial Robotics
ECE 6325 - State-Space Control Systems, ECE 6335 - Digital Control Systems, ECE 6390 - Linear Multivariable Control Systems, ECE 7333 - Optimal Control Systems, ECE 7334 - Advanced Digital Control Systems

Blackboard Login Information

Please note: **Not all instructors choose to use the Blackboard course management system.**

Blackboard:

Bb Login:	accessUH.uh.edu or elearning.uh.edu or uh.edu/blackboard
Username:	same as your **CougarNet UserID***
Password:	same as your **CougarNet Password****

Reset **CougarNet Password:** *(3 options)*

- go to **https://accessUH.uh.edu** > **Change CougarNet Password** > select *"I forgot my CougarNet password or need it reset."* > follow prompts.
- go to **http://uh.edu/password** > select *"I forgot my CougarNet password or need it reset."* > follow prompts.
- go to **www.uh.edu/infotech** > Password Reset > select *"I forgot my CougarNet password or need it reset."* > follow prompts.

Change **CougarNet Password:** *(3 options)*

- go to **https://accessUH.uh.edu** > **Change CougarNet Password** > select *"I need to change my CougarNet password."* > follow prompts.
- go to **http://uh.edu/password** > *"I need to change my CougarNet password."* > follow prompts.
- login to **CougarNet** > **Control+Alt+Delete** > click **Change Password** in dialog box > enter **Old Password** > enter **New Password** > **Confirm.**

Need Help?

Contact the UIT Support Center

- ***by phone***: 713-743-1411
- ***online***: **support@uh.edu**
- ***live chat***: **www.uh.edu/infortech/livechat**
- ***in person***: Room 58 (basement) or 1st floor of MD Anderson Library
- ***UH Help*** tab in Blackboard

If you do not know your **CougarNet UserID, you may request it at **https://accessuh.uh.edu**, contact UIT Support Center at 713-743-1411, or go to the Engineering Computing Center (ECC) front desk (W-129, Engineering Bldg. 2) with your Cougar Card - ECC staff can help you.*

***If you do not know your **CougarNet password**, see options under "Reset CougarNet Password" above.*

Academic Honesty Statement & Email Agreement

Name: (printed) _____

Confirm that the following statements are true and then sign and date below.

Academic Honesty Statement

- ✓ I have read the University of Houston Academic Honesty Policy contained in the UH Undergraduate Catalog available at http://catalog.uh.edu/content.php?catoid=8&navoid=1352
- ✓ and the ECE 2300 Position on Academic Honesty contained in the Course Policy Document and available on the course web site and agree to abide by its provisions. I understand that the *Department of Electrical & Computer Engineering* takes academic honesty very seriously and, in the cases of violations, penalties may include suspension from the University of Houston.

UH E-mail Alias Agreement

- ✓ I have read the University of Houston Information Technology website discussing UH e-mail aliases (http://www.uh.edu/infotech/services/accounts/email/update-student-address/index.php). I understand how to use this alias to receive e-mail through my outside provider.

- ✓ I understand that it is my personal responsibility to configure this alias properly to receive mailings from the university.

- ✓ I understand that the ECE department will use this e-mail alias for all official correspondence.

Signature: _____

UH E-mail Alias: _____

Date: _____

Submit this form to your professor by ___.