Electrical Engineering 4330/7330

Introduction to Mechatronics and Robotic Vision

Prerequisite:
ECE 3220 (Computing for Embedded Systems),
or ECE 4220 (Real Time Embedded Computing),
or C/C++ programming language,
or instructor's consent (and Linear Algebra!!!).

G. DeSouza

August 2017

University of Missouri - Columbia
Electrical & Computer Engineering Department
Columbia, MO 65211

Professor: G. N. DeSouza
E-mail: DeSouzaG@missouri.edu
Office: 325 EBW (stop by whenever you feel like)
Web: **http://web.missouri.edu/~desouzag/**

Lecture: 3 lectures of 50 mins each.
Lab: 2 lab hours / week in EBW 107

Lab TA: Ali Shafiekhani
Office: TBA
E-Mail: **as897@missouri.edu**

Background: The portmanteau "Mechatronics" (*mecha* for mechanisms, and *tronics* for electronics) was first coined by Mr. Tetsuro Mori, a senior engineer at the Japanese company Yaskawa, in 1969. The term was originally created to designate the field of study of automata (self-operating machines) from an engineering perspective. Today, this interdisciplinary degree involves courses not only in mechanics, electronics, robotics and control engineering, but also in computer engineering, software engineering, communications, digital signal processing and even nanotechnology (MEMS) and biotechnology.

Being such a broad area, many universities around the world offer today either a specific four-year degree or a multi-disciplinary degree in Mechatronics Engineering – the latter is usually obtained by taking classes from departments such as ME, ECE, and CS. Since every mechatronic system requires a mechanism and the sensors/actuators to control such mechanism, in this introductory course, we will focus on three major topics, as explained next.

Course Description: Course focuses on: 1) mechatronic systems and their components; 2) the mathematical tools used to model industrial and mobile robots; and 3) vision sensors, their underlying models and the algorithms that allow us to control and interact with robots

Lab: In the lab, students will gain practical experience in writing programs to control real robots: industrial and mobile robots. The students will develop Matlab, C and/or C++ code to interface with sensors such as cameras, sonars, contact, etc. and use that sensory information to guide the robots to perform simulated assembly tasks and indoor navigation. The sequence of lab experiments build on the previous ones and, by the end of the semester, the students will be able to develop a complete system that will allow teams to compete on a game involving vision-guided robotics.

Text: Introduction to Robotics: Analysis, Control, Applications, 2nd Edition Saeed B. Niku Wiley, Sept. 2010. http://www.wiley.com/WileyCDA/WileyTitle/productCd-EHEP001617.html

Many handouts will be provided and the following references were put on reserve in the CoE Library and may be used throughout the semester:

Introduction to Autonomous Mobile Robots, by Siegwart, Nourbakhsh, and Scaramuzza, Second Edition, The MIT Press, 2011.
Introduction to Mechatronics and Measurement Systems, by David G. Alciatore and Michael B. Histand, McGraw-Hill, 2007,
Emerging Topics in Computer Vision, Gerard Medioni and Sing Bing Kang Prentice Hall, 2005.
Computer Vision: A Modern Approach, D. Forsyth and J. Ponce, Prentice Hall 2002.
Environment Learning in Indoor Mobile Robots, Juan Andrade-Cetto and Alberto Sanfeliu, Springer, 2006.

Prerequisites: ECE 3220 (Computing for Embedded Systems), ECE 4220 (Real Time Embedded Computing), **or** C/C++ programming (and Matlab) – Linear Algebra!

Course Grading:

Undergrad Students:

Midterm	25 points
In-class Final Exam	35 points
Programming and Lab assignments	30 points
Continuous Assessment	10 points

Grad Students:

Midterm	15 points
In-class Final Exam	25 points
Programming and Lab assignments	25 points
Projects	25 points
Continuous Assessment	10 points

Grad Students will be assigned two Projects: a small project on camera calibration and a larger one on their choosing. For Project 2, grad students will deliver a proposal by week 8th, present their project in week 15th and turn in a report in week 16th.

Continuous Assessment:

1. Attendance (participation)
2. Readiness tests (preparation)
3. Tutor observation during class and group work (preparation, participation, and process)
4. Submitted group work (product)
5. Peer assessment (prep. and participation)

Grad Scale:

Undergrad students: A-to-F scale with +/-. Grad students: A, B, C, or F with +/-.

Topics:

Lectures	Topic
1	Introduction to Mechatronics
3	Sensors and Actuators
2	Matrix transformations and coordinate systems
1	Computer Vision
2	Camera Calibration
2	Basic Image Processing Algorithms
2	Stereo and Multi Vision
3	3D Reconstruction and Pose Estimation
1	Industrial Robots
3	Joint, Links, Denavit-Hartenberg Representation
4	Forward and Inverse Kinematics
1	Visual Servoing: Image Based and Position Based
2	Trajectory Planning
1	Mobile Robots
4	Structured and Unstructured Environments, Control Architectures, Vision-guided Navigation and Localization
2	Robot Operating System (ROS)
1	Publisher & Subscriber
2	Concepts and Practice (Packages)
1	LeapMotion

Total: 38 lectures, 2 reviews, 2 exams, 2 days of student presentations

Lab Assignments:

Lab Experiment 1: Camera Calibration
Lab Experiment 2: Bin-picking: Object Detection/Recognition and 3D Pose Estimation.
Lab Experiment 3: D-H Representation, Forward and Inverse Kinematics
Lab Experiment 4: ROS – Publisher and Subscriber
Lab Experiment 5: ROS
- a) LeapMotion
- b) Puma control

Lab Experiment 6: Robotic Competition (Robots Playing a "Basketball/Baseball" Game).

Academic Dishonesty: According to University policy, instructors are required to inform students of specific guidelines regarding cheating in their courses. Instructors are required by University policy to report incidents of cheating to the Office of the Provost. In compliance with this rule, all incidents of cheating by students in this course will be reported to the Office of the Provost for determination of possible disciplinary action.
Any student found to have cheated during an ***exam or lab*** will be given an "F" grade for the ***class*** and the evidence will be sent to the Provost's Office. Students submitting the same or similar solutions to a programming homework will be given a 0 for the assignment and the evidence will be sent to the Provost's Office for determination of possible disciplinary action. Second occurrences of cheating in a homework will lead to an "F" grade for the class.
Unless an assignment is specifically structured as a group project, duplicate homework written in collaboration with others is **not** acceptable. Although it is permissible to discuss the homework with others, these discussions should be of a general nature. All work at a detailed level must be done on your own. *Students submitting the same or similar solutions to the homework will be considered as having cheated.* No statements or actions made by anyone can alter this policy.

Statement on ADA:

Students with Disabilities:
If you anticipate barriers related to the format or requirements of this course, if you have emergency medical information to share with me, or if you need to make arrangements in case the building must be evacuated, please let me know as soon as possible.
If disability related accommodations are necessary (for example, a note taker, extended time on exams, captioning), please establish an accommodation plan with the Disability Center (disabilitycenter.missouri.edu, S5 Memorial Union, 573- 882-4696), and then notify me of your eligibility for reasonable accommodations. For other MU resources for persons with disabilities, visit ada.missouri.edu.

Written Laboratory Report Format: A formal project report from each laboratory team is to be submitted to your lab instructor. Each lab team is required to submit **one team report** per lab project. The lab report flow should be logical in that each step in the lab should be documented in the order conducted. The format for written reports will be determined by the lab instructor.

LAB ORGANIZATION:

1. Each student will perform the following tasks:

a) Prelab report
b) Programming
c) Postlab report.

2. Each student should work independently and should NOT give their programs to others. Students are responsible for possible "proliferation" of their programs. Any violation will lead to penalty.

LAB TASKS:

1. Prelab Report:

a) Write pseudo code or a flow chart for the program. Pseudo code should be structured and descriptive rather than technical.
b) Other specific works assigned in the lab handout.
c) The pseudo code or the flow chart must be turned in at the beginning of the lab period.
d) The report must be typed.

2. Lab Work:

a) Your T.A. will check your program during the lab period.
b) If the program works completely following the program requirements, you will earn 50 points.
c) Partial credits will be earned upon the work progress.

3. Postlab Report:

a) Due by next lab period.
b) Lab report format:

i. Abstract
ii. Objective
iii. Background/Theory
iv. Procedures
v. Results
vi. Conclusions
vii. Appendices (e.g. programs).

c) Report must be clear and neat. Programs must be structured and commented adequately. The conclusions should contain what the overall experiment taught you, specific concepts learned from the lab and, if the lab did not work, why.
d) The report must be submitted directly to the TA. The .c and .cpp files must be included separately from the report, which may be in MS Word, or PDF format. No late reports will be accepted.

LAB GRADING:

1. Each experiment is worth 100 points including LAB 1.

2. Experiments are graded as follows:

    a) Prelab 10 points
    b) Program 50 points
    c) Postlab 40 points (No credit for late report)

i. For the lab work (Program):

    50 points, if completed during the lab period
    30 points, if completed before the next lab period
    No credit for labs which work after the next lab period.

ii. Postlab report grading guide lines:

    Objective 5 points
    Program 20 points
    Conclusion 15 points.

iii. There may be lab quizzes during the semester to check team participation.

COMPUTER FACILITY:

The lab sessions will be held in Lafarree C1246. The combination to the door will be given in class.

LAB REGULATIONS:

1. No food or drink in the lab.
2. Do not give lab combination to others.
3. Do not leave your own software or programs on the computers in the lab.
4. Do not put backpacks etc. on the computer keyboards or mice.

Fall 2017

	Lab1	Lab2	Lab3	Lab4	Lab5	Lab6
Week 1						
Week 2	Intro					
Week 3	Session (Pre)					
Week 4	Session					
Week 5	Report	Session (Pre)				
Week 6		Session				
Week 7		Report	Session (Pre)			
Mid-Term – Oct 11th						
Week 8			Session			
Week 9			Report	Session (Pre)		
Week10				Session		
Week11				Report	Session (Pre)	
Week12					Session	
Week13					Report	Session (Pre)
Thanksgiving Break (Nov.20 - Nov.24)						
Week15		**Student Project Pre-Report**				Session
Week16		**Student Project Presentations**				Report
FINAL EXAM: TBA (Final Project Report)						