1. **MEE623/MEE498 – Robot Vision Control**

   Spring 2017

   Course (catalog) description

   Generalized images; segmented images; geometrical structures; relational structures; robot machine vision systems.

   Long description Vision comes naturally to many animal species including humans. An image provides information related to position, orientation, shape and color of objects. Sequence of images provide motion cues, and sequence of synchronized images from multiple perspectives can be used to extract three-dimensional information. With recent advances in computer vision that puts vision as an advanced sensing modality, it becomes a natural choice to enable autonomous operation in robots. Therefore in addition to acquiring and interpreting images, robot vision deals with deriving feasible actions that must be carried out in response to those images. This course will focus on topics in image understanding such as image representation, feature extraction, segmentation, optical flow, and structure from motion. With the intent of using the image information to control a robot, an equal portion of the course will be devoted to robot control topics such as forward and inverse kinematics, camera calibration (to determine the relative position and orientation of the robot itself), visual servoing, and target tracking. Projects involving image processing, information extraction, and vision based control of mobile robots and manipulators will be assigned during the course of the semester.

   Course objectives On completing this course, the student will be able to:

   - Identify contemporary methods in Robot vision and control research (k)
   - Implement image processing and computer vision algorithms to extract features of interest from simple images (a,k)
   - Formulate a strategy to map the output of a camera sensor to robot input (g,e)
   - Work in a team on multiple projects focusing on computer vision and robot control (b,d,e)

2. **Prerequisites:** MEE 522 / MEE 322. This course expects familiarity with linear algebra, classical control theory, robotic manipulators, and programming in MATLAB/C++. Although MATLAB is encouraged as an initial platform for proof-of-concept, several projects may require a low-level implementation in C or C++ for real-time operation. You are expected to have read the pre-assigned material (reading and homework assignments) before coming to the class. *You are also expected to bring a laptop with MATLAB to class to try out sample algorithms during the lecture.*

3. **Credit and contact hours:** 3 Cr. hrs. Contact hours is one 160 minutes lectures/week

   Meeting times

   Tue 6:00p–8:40p EB 101

4. **Instructor:** Sachit Butail

   EB 148
   Office hours: Mon 1:00–2:00p, Tue 2:00–4:00p, or by appointment
   sbutail@niu.edu
   (815) 753-9987

5. **Teaching assistant:** Revanth Konda

   EB 231
   Office hours: Mon, Wed 12:30–2:00p
   Z1807320@students.niu.edu

6. **Textbook(s) and/or other required materials:**

   There are no required textbooks for this course. You will be provided with reading assignments and lecture slides. Lectures will assume that you have come prepared and will focus on answering questions and reinforcing concepts. Below are suggested texts that you may be use to supplement your learning.

   - Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Peter Corke, `http://www.petercorke.com/RVC/index.php`
   - Multiple View Geometry in Computer Vision, Richard Hartley & Andrew Zisserman, Cambridge University Press, 2003, `http://www.robots.ox.ac.uk/~vgg/hzbook/`
   - Introduction to Robotics: Mechanics and Control, John Craig, Pearson
   - Machine Vision: Automated Visual Inspection and Robot Vision, David Vernon, `http://homepages.inf.ed.ac.uk/rbf/BOOKS/VERNON/vernon.htm`
   - Computer Vision: Algorithms and Applications, Richard Szeliski, `http://szeliski.org/Book/`

   Below is a list of software planned for demonstrating the methods and algorithms we will learn in this course:

   - MATLAB (R2009 onwards, must have image processing toolbox)
   - OpenCV (`http://opencv.org/`)
   - Robotics toolbox (`http://petercorke.com/wordpress/toolboxes/robotics-toolbox/`, runs in MATLAB)

7. **Specific Course Information:**

   i. **Homeworks:**

   There will be four homework assignments as part of this course. MEE623 students will have additional homework problems. These will be due as per the schedule (Table 1). You are encouraged to collaborate on these, however, the work you submit should be entirely your own. Copying homework, first offense will get you 0 points on the homework; second offense will get you 0 points on the homework and -1% on the final grade; third and subsequent offense will get you 0 points on the homework and -5% on the final grade. In case of a late submission, 10% of maximum marks will be docked for every additional day; after three days no marks will be awarded.

   ii. **Project:**

   The following is a list of projects planned as part of this course (maximum team size):

   - Visual inspection of fruits and vegetables (3)
   - Locating parts on the shop floor (3)

- Object following with mobile robot (4)
- Pick-and-place operation with manipulator (4)

iii. **Grading:**

- Homework Assignments (4): 40%
- Projects (4): 60%

iv. **Note:**

- It is your responsibility to check your scores on Blackboard periodically. Scores will only be updated for the most recent homework/quiz/project/exam.

8. **Specific goals for the course:**

   Coverage of ABET Outcomes:

   a. an ability to apply knowledge of mathematics, science, and engineering

   b. an ability to design and conduct experiments, as well as to analyze and interpret data

   d. an ability to function on multidisciplinary teams

   e. an ability to identify, formulate, and solve engineering problems

   g. an ability to communicate effectively

   k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

9. **Topics covered:** The topics will be covered in the following order and can be found with the same name in the textbook. Please read relevant chapters in the textbook before attempting homework assignments

   - Image processing, segmentation, distortion
   - Feature selection, Optical flow
   - Camera calibration
   - Mobile robots
   - Manipulators
   - Image based visual servoing
   - Machine learning

Accessibility Statement

If you need an accommodation for this class, please contact the Disability Resource Center as soon as possible. The DRC coordinates accommodations for students with disabilities. It is located on the 4th floor of the Health Services Building, and can be reached at 815-753-1303 (V) or drc@niu.edu. Also, please contact me privately as soon as possible so we can discuss your accommodations. The sooner you let us know your needs, the sooner we can assist you in achieving your learning goals in this course.

Academic Integrity

Please carefully go through `http://www.niu.edu/ai/students/`. Please discuss with me if you have doubts about what constitutes dishonesty, plagiarism, and cheating. You are responsible for your work!

Table 1: Tentative Schedule. The readings can be found at `https://goo.gl/b7OeET`. Chapters will be scanned and posted on this location.

Date	Topic	Readings and references	Hwks	Proj.
1/17/17	Image representation, background subtraction, edge detection	Chapter 2, Computer vision (CV_chapter2.pdf), edgeNotes(link), Canny1986, Piccardi2004		
1/24/17	Image analysis, template matching, Hough transform, Fourier descriptors	Vernon1991, Hough transform(link), FourierDescriptors		
1/31/17	Scale Invariant Feature Transform (SIFT) features	Lowe2004	1 due	
2/7/17	Position and orientation, Camera models, camera calibration, Epipolar geometry	Chapter 6, Hartley & Zisserman		1 due
2/14/17	Distortion, omnidirectional cameras, depth sensing	Chapter 7, Hartley & Zisserman, Notes		
2/21/17	Optical flow	OpticalFlow.ppt, Horn1991	2 due	
2/28/17	Structure from motion (factorization approach)	Tomasi1992, Poelman1997		
3/7/17	Face recognition	Turk1991		2 due
3/14/17	Spring Recess		3 due	
3/21/17	Manipulators, transformations	Chapter 2, Introduction to Robotics		
3/28/17	Inverse and forward kinematics	Chapters 3 and 4, Introduction to Robotics		
4/4/17*	Robot control (No Lecture, Slides will be posted)	Chapter 9, Introduction to Robotics	4 due	
4/11/17	Image based visual servoing, Position based visual servoing	Chaumette2006, Chaumette2007		3 due
4/18/17	Visual servoing contd., Mobile robots	Chapter 4, Robotics Vision and Control		
4/25/17	Target tracking (Kalman filter)	Notes, Kalman filter(link)		
5/2/17	Machine learning: dimensionality reduction, neural networks	Ghahramani2004, notes		4 due