



Robotic Vision: Sensing, Localization and Control

Class Schedule:

Mon. & Wed., 5:30-6:50pm, ERB 129

Office Hours:

Mon. & Wed., 1:30-3:30pm or by appointment

Course Website:

http://ranger.uta.edu/~gianluca/teaching/CSE4392-5369_F14/

Teaching Assistant:

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Office Hours: Tu-Th: 11am-noon, ERB413

Faculty:

Dr. Gian Luca Mariottini

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Course Overview:

Vision is arguably the most important of the five senses, and is commonly used by humans in many daily tasks (e.g., for recognizing objects or locations, as well as for navigation). Endowing robots with such an expert and autonomous sense of vision has been a dream of scientists and engineers for over half a century. Potential fields of interest are space exploration, home-, industrial-, and medical-image analysis.

In this course, students will be introduced to the basic techniques of vision-based robot perception, recognition, 3-D localization, and navigation. The topics covered include a description of the main robotic and vision-sensing devices (laser, stereo cams, Kinect, etc.), as well as of the basic techniques for image processing. Particular attention will be given to object recognition, robot-localization and mapping, and navigation techniques.

Students will work individually and in groups to analyze vision-based robotics problems and to design software solutions. After successfully completing this course, students will be able to apply a variety of state-of-the-art vision techniques for the design of efficient algorithms in order to address complex problems of vision-based sensing, localization and navigation.

Course Prerequisites:

- CSE 4392/5369 is self-contained and does not need special prerequisites.
- Matlab programming experience is required. If you are unfamiliar, please check this: <http://www.math.ucsd.edu/~bdriver/21d-s99/matlab-primer.html>. During the course we will also make use of the MATLAB's [Epipolar Geometry Toolbox](#), which can be efficiently used for creating [vision-based robot simulations](#).

Course Goals:

CSE 4392/5369 is designed to:

- Introduce the student to fundamentals of robotics and vision-based sensing.
- Explore the mathematical/algebraic foundations of single- and multi-view geometry for pose and 3-D scene estimation.
- Explore and familiarize with vision-based robot navigation techniques.
- Learn Bayesian techniques for robot localization.

Course Outcomes:

Upon successful completion of the course, each student will be able to:

- Recognize the features and peculiarities of different robotic and vision devices.

- Understand rigid body kinematics and relationships between 3-D reference frames
- Describe image formation and camera models. Discuss/compare the characteristics of different vision sensing devices (pinhole, omnidirectional, stereo, etc.)
- Understand and discuss different strategies for feature detection, matching and tracking.
- Understand and implement 3D structure and motion estimation algorithms.
- Understand and design vision-based robot navigation algorithms.

Course topics*

- **Basics on Robotics and Computer Vision**
(TOPICS: Intro to Robotics; Intro to Computer Vision)
 - **Image-based Feature Detection, Matching and Tracking**
(TOPICS: Image noise; Feature detection and matching; Feature tracking)
 - **Generalized Camera Models**
(TOPICS: Rigid-body kinematics; Camera models (pinhole, stereo, Kinect))
 - **Vision-Based Estimation, Calibration and Localization**
(TOPICS: Camera Calibration; Resectioning and Least-Squares)
 - **3-D Reconstruction and Probabilistic Robotics**
(TOPICS: Stereo Triangulation; Multi-view Geometry; Probabilistic Localization)
 - **Vision-Based Robot Navigation**
(TOPICS: Visual Servoing; Trajectory generation and tracking; Wall following)
- (*please note course topics & schedule are preliminary and might undergo slight changes)

Tentative Schedule:

		Teaching topic
August	25	Intro
	27	<i>no class</i>
September	1	Labour Day
	3	Robot Structures
	8	Intro to Computer Vision
	10	Pinhole and Stereo camera Mod.
	15	Rigid Body Transformations (1)
	17	Rigid Body Transformations (2)
	22	General Pinhole & Stereo Model
	24	EGT: Tutorial
	29	Basics of Image Processing
October	1	Edge and Corner Detection
	6	Feature Tracking and Matching
	8	OpenCV: Tutorial
	13	More on Resectioning (1)
	15	More on resectioning (2)
	20	Epipolar Geometry: basics
	22	Epipolar Geometry Estim.
	27	Vision Based Navigation: Intro
	29	Vision Based Navigation: Intro
November	3	Advanced Vision Based Navigation
	5	<i>OpenCV tutorial</i>
	10	<i>OpenCV Intro</i>
	12	Vision Based Navig. IBVS+PBVS
	17	Probabilistic Robotics: Intro
	19	Basics of Estimation (LS, WLS, R-LS)
	24	KF

	26	EKF
December	1	Applications of EKF
	3	Project Presentations
	8	Final exam day (5:30 - 8pm)

Course text:

There is no required textbook for this course.

Other course material [*pdf* of the lecture slides, technical papers, exercises,...] will be made available on the course webpage (see pg.1).

However, some suggested references are:

- B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo
"Robotics: Modelling, Planning and Control", 3rd Edition, Springer, 2009
- E. Trucco, A. Verri
"Introductory Techniques for 3-D Computer Vision", Prentice Hall, 1998
- Wolfram Burgard, Dieter Fox, Sebastian Thrun
"Probabilistic Robotics", MIT Press
- R. Hartley, A. Zisserman
"Multiple View Geometry", 2nd Edition, Cambridge Univ. Press 2004
- Y. Ma, S. Soatto, J. Kosecka, S. Sastry
"An Invitation to 3-D Vision. From Images to Geometric Models", 2003

Office Hours

The instructor is generally available before or after class and by appointment, as well as at the office hours scheduled above.

Since this is a special-topic course in robotics, and since each presented topic contains many exciting sub-fields, the interested students who want to know more about a specific problem are encouraged to schedule an appointment with Dr. Mariottini for additional material.

Course Assignments, Exams and Policies

Class attendance and participation

In CSE 4392/5369, the students will be presented with the state-of-the-art in vision-based robot control, localization and navigation technologies. Most of the topics are active fields of research in the robotics community. I strongly encourage the students to attend each class and to actively contribute with in-class discussion, when necessary. Students must arrive on time at class.

During the whole semester, I like to interact with the participants and ask them to actively participate to complete informal small in-class exercises. These informal activities will not be graded but will be used as a feedback or plan activities.

Homeworks and Course Project

Students will be graded based on homework assignments and a major course project.

Homeworks will mostly consist of theoretical questions, programming assignments in MATLAB, etc. related to the topics of the course. Dates for the homeworks will be announced in class. Regarding homeworks policies, please refer also to the Course Policy section.

The course project will focus on designing and implementing a particular algorithm from a list provided in class, and walking through details related to its analysis and design. For their final project, students will have the possibility to also use up to 4 [iCreate](#) robotic platforms (by iRobot) as well as one ARDrone robot. USB and Kinect cameras and laptops are also available to program the robot and process data from the sensors.

Additional projects related to the course topics and proposed by students can be added to the list. Students need to present (by a deadline that will be announced in class) an abstract indicating the title on the project, a short description, and the members of the team. Failure in providing

this abstract by the deadline will result in a zero to the project part of the exam. In evaluating the projects design, particular attention will be given to the projects that excel in creativity and effectiveness of their result. The course project can be done either individually or in a team. Students will report their findings in a 8-10 page research report, and an in-class oral presentation (with Power Point slides) during last day of class.

For students enrolled in the graduate section CSE 5369 the homework assignments, as well as the course project, will contain additional problems not required for students of CSE 4392.

Grading policy

Tentatively, course grades will based on the following:

Assignments	% of final grade	Percent Grade
Homeworks (total)	60 %	90% - 100% A
Course Project	30 %	80% - 89.9% B
- Proj. Presentation	10 %	70% - 79.9% C
		60% - 69.9% D
		< 60% F

Final Project/Homework Late Submission Policy

Late submissions for the *final project* and *homeworks* will be penalized according to:

- Late by 1-24 hrs: 5% deducted from actual score.
- Late by 24-48 hrs: 25% deducted from actual score.
- Late by 48-72 hrs: 45% deducted from actual score.
- Late by more than 72 hrs: Will receive a zero.

Course/University Policies and Services

Attendance

At The University of Texas at Arlington, taking attendance is not required. Rather, each faculty member is free to develop his or her own methods of evaluating students' academic performance, which includes establishing course-specific policies on attendance. As the instructor of this section, I will not take attendance.

However, as stated above, attendance is strongly suggested at the first day and each class session. Students are encouraged to arrive on time and attend the full class period.

Participants who need to miss class for religious observance or for a pressing personal or family matter, should contact the instructor prior to missing class or as soon as possible. Participants should plan on getting the information about the missed class from a peer.

I strongly encourage in-class collegial behaviour as well as between the project group members. Non-collegial behavior includes working on other tasks during class time (text messaging, e-mailing, Web surfing, doing crosswords/Sudoku, having private conversations, etc.). Another example of non-collegial behavior could be the creation of unconstructive conflicts inside a group.

Finally, I positively value the students' active participation to in-class discussions. This is extremely important because gives the instructor (and the students too!) a feedback on the audience understanding.

Drop Policy:

Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will**

not be automatically dropped for non-attendance. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (<http://www.uta.edu/aao/fao/>).

Americans with Disabilities Act:

The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the Americans with Disabilities Act (ADA). All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability or by calling the Office for Students with Disabilities at (817) 272-3364.

Title IX:

The University of Texas at Arlington is committed to upholding U.S. Federal Law "Title IX" such that no member of the UT Arlington community shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity. For more information, visit www.uta.edu/titleIX.

Academic Integrity:

Students enrolled all UT Arlington courses are expected to adhere to the UT Arlington Honor Code:

I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.

I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.

UT Arlington faculty members may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System Regents' Rule 50101, §2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University.

Electronic Communication:

UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at <http://www.uta.edu/oit/cs/email/mavmail.php>.

Student Feedback Survey:

At the end of each term, students enrolled in classes categorized as "lecture," "seminar," or "laboratory" shall be directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT

Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit <http://www.uta.edu/sfs>.

Final Review Week:

A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week *unless specified in the class syllabus**. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

** The policy on final review week might change for this class. Students will be informed by email ahead of time.*

Emergency Exit Procedures:

Should we experience an emergency event that requires us to vacate the building, students should exit the room and move toward the nearest exit. When exiting the building during an emergency, one should never take an elevator but should use the stairwells. Faculty members and instructional staff will assist students in selecting the safest route for evacuation and will make arrangements to assist individuals with disabilities.

Student Support Services:

UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at www.uta.edu/resources