Algorithms for Sensor-Based Robotics (ASBR)

M E 397 (#19250)
Spring 2022

Instructor Info

Farshid Alambeigi, Ph.D.
AHG 2.320
Office Hrs days: Mondays
Office Hrs time: 1:00-2:00 p.m.
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Course Info

Tues & Thurs
5:00 p.m.-6:30 p.m.
ETC 3.108 [Online/Zoom]
Canvas and Piazza

TA Info

Pulkit Singhal
Wed 3-4 p.m., Fri 11-12 p.m.
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Canvas/Zoom

Description of the Course

This course focuses on using advanced mathematical concepts in linear algebra, stochastic processes, and optimization to develop applied algorithms for robotic systems utilizing various imaging systems (e.g., cameras, optical trackers, and X-rays) and sensors.

These generic concepts will assist roboticists in all phases of kinematics/dynamics modeling (e.g. rotations and group theory, axis-angle and quaternion representations), preparation (e.g., calibration and registration concepts), motion planning, and execution (e.g., defining virtual fixtures, visual servoing, and optimization-based robot control). This robotics course also describes examples of such algorithms in various areas including, but not limited to, robotic surgery, mobile platforms, manipulation, and human-machine systems.

Prerequisites

This course is intended for graduate students and I assume students have a rudimentary understanding of

- Robotics: you will need to be familiar with basic concepts of robotics such as rotation matrices, Jacobians, Transformations, etc. Although, we try to briefly cover these topics in the class.
- Mathematical background:
  – You will need to work with coordinate transformations and linear approximations
  – Calculus will be assumed
  – Linear algebra is highly recommended.
  – Probability/statistics will be helpful.
- Programming:
  – Homework can be handed in MATLAB and needs to be well discussed and documented.
  – We will need to be able to run your programs.
  – Familiarity with basic data structures is important.
  – Your lab partner choice is important. Pick complementary skills!

References

- Murray, R.M., Li, Z., Sastry, S.S., "*A Mathematical Introduction to Robotic Manipulation.*"
- Kevin M. Lynch, and Frank Chongwoo Park. "*Modern Robotics: Mechanics, Planning, and Control.*" Cambridge University Press, 2017.
- Corke, Peter. "*Robotics, vision and control: fundamental algorithms in MATLAB®*" second, completely revised. Vol. 118. Springer, 2017.
- Bruno, Siciliano, Sciavicco Lorenzo, Villani Luigi, and Oriolo Giuseppe. "Robotics: modelling, planning and control." Advanced Textbooks in Control Signal Processing 4 (2009): 76-82.
- Taylor, Russell, and Stéphane Lavallée. "*Computer-integrated surgery: technology and clinical applications.*" Mit Press, 1996.
- Siciliano, Bruno, and Oussama Khatib, eds. "*Springer handbook of robotics*." Springer, 2016.
- Choset, Howie M., Seth Hutchinson, Kevin M. Lynch, George Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun. "*Principles of robot motion: theory, algorithms, and implementation.*" MIT press, 2005.
- Laub, Alan J. "*Matrix analysis for scientists and engineers.*" Vol. 91. Siam, 2005.

Assessment

- *Take Home Assignments (THAs)*: Course grade is based on THAs on Canvas:
  – 4 *take home exams* (called "THAs") done alone or in teams of two.
  – THAs typically are combinations of handwritten and programming questions.
  - Group Presentation of the assignment is mandatory for some of THAs.
  - For this semester, we will work on 4 different robotic manipulators through the semester. THAs will be performed based on these robots.

FAQs

Do we perform any experiments or use hardware/robots in this course?

We might use Zivid one 3D camera to collect point cloud data for the calibration and registration programming assignments. All assignments will be performed on Kuka LBR iiwa, Kuka KR Quantec,Franka Emika Panda, and YAskawa SDA10F.

Is there a final exam for this class?

No! but we will have assignments in the form of mini-take home exams!

Is there any Bonus/optional project for this course?

I have not decided yet! We might have an optional course project depending on the time line of the course.

What's your main goal for teaching this class?

My teaching philosophy for this class is to help students learn practical concepts/algorithms for sensor-based robotics and build confidence to approach, model, and solve any generic robotic-related problems.

- Before the end of Week 3, groups and appropriate robots need to be assigned.
- *Term Project*: We might have a term project depending on the class preference.
- Homework assignments are due in class. *For late assignments, check the Late Assignment policy*.
- Assignments Dues are typically 2/3 weeks from the day we will hand-in them, depending on the size of assignments.

Grading

90%	∼ 4 THAs
10%	∼ THA Presentations

- The final grade will be assigned using curved grading based on the grand average and standard deviation of the above grades.

Programming Problems

- Programming projects build on each other and typically involve using algorithms discussed in class to determine an "unknown" quantity
- I will provide several debugging data sets with answers and an "unknown" data set
- You should hand in a report containing:
  – Description of the problem and method used to solve it
  – Description of the program structure & who did what
  – The "answer" & short discussion of the answer (why you think it is correct). I recommend that you include also a discussion of the debugging data. Also, the answers should not be embedded somewhere in a program printout. Put them clearly in the report.
  – The documented program listing
  – Include full bibliography and acknowledge any consulting help you get on algorithms

Course Web Page:

Course materials will be posted on Canvas. This includes course syllabus, class notes, recorded lectures, announcements, and homework assignments.

Miscellaneous Items

- The deadline for dropping a course without possible penalty can be found in the current semester UT calendar online.
- Allegations of Scholastic Dishonesty will be dealt with according to the procedures outlines in Appendix C, Chapter 11 of the General Information Bulletin.
- Student misconduct and academic integrity issues will be reported to Office of the Dean of Students.
- If you are a student with a disability, or think you may have a disability, and need accommodations please contact Services for Students with Disabilities (SSD). You may refer to SSD's website for contact and more information. If you are already registered with SSD, please deliver your Accommodation Letter to me as early as possible in the semester so we can discuss your approved accommodations.
- The university is committed to creating an accessible and inclusive learning environment consistent with university policy and federal and state law. Please let me know if you experience any barriers to learning so I can work with you to ensure you have equal opportunity to participate fully in this course. If you are a student with a disability, or think you may have a disability, and need accommodations please contact Services for Students with Disabilities (SSD). Please refer to SSD's website for contact and more information. If you are already registered with SSD, please deliver your Accommodation Letter to me as early as possible in the semester so we can discuss your approved accommodations and needs in this course.
- Collaboration on homework assignments with other students is encouraged. However, all the submitted must by your own work. Any evidence of plagiarism or other forms of scholastic dishonesty will be grounds for a failing grade of the course.

Late Assignment Policy

Each student/team has a 48 hours/semester budget for handing in late assignments. You can use this budget for one assignment or through the semester without losing any grade. However, if you use the entire budget and have another late assignments, your grade for those assignments would be zero!

Emailing Policy

Please put "ME397-ASBR" in the subject of your emails if you want the instructor and TA(s) find and answer your emails quickly.

Sharing of Course Materials is Prohibited

No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating.

It is a violation of the University's Student Honor Code and an act of academic dishonesty. I am well aware of the sites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.

Statement on Learning Success

Your success in this class is important to me. We will all need to be adaptable because we all learn differently. If there are aspects of this course that prevent you from learning or exclude you, please let me know as soon as possible. Together we'll develop strategies to meet both your needs and the requirements of the course. I also encourage you to reach out to the student resources available through UT. Many are listed on this syllabus, but I am happy to connect you with a person or Center if you would like.

Statement on Flexibility

In acknowledgement of COVID 19 and its impact on the University of Texas at Austin community, this course will reaffirm one of the core values here at UT Austin: responsibility. Our responsibility to ourselves and each other is to put our humanity in the forefront of our academic pursuits. With that being said, this semester I commit to being adaptable in this time of great need, which is reflected in the course policies below around attendance, grading, and assignments/exams.

If you experience any hardships such as illness, accident, family crisis please know that these policies may be amended and therefore you should communicate with me as soon as you feel comfortable doing so. If for any reason you do not feel comfortable discussing with me, please visit Student Emergency Services. For additional campus resources, please visit protect.utexas.edu.

Class Schedule (Tentative)

All instructions, assignments, readings, rubrics and essential information will be on the Canvas website. Check this site regularly and use it to ask questions about the course schedule. Changes to the schedule may be made at my discretion and if circumstances require. It is your responsibility to note these changes when announced (although I will do my best to ensure that you receive the changes with as much advanced notice as possible).

MODULE 1: Robot Kinematics

Week 1	Syllabus and Introduction to the course, Rigid body Motion and Transformations, Rotation Matrices.
Week 2	Axis-Angle, Euler angles, Quaternion representations, Homogeneous Transformations. (THA1 posted)
Week 3	Angular Velocity, Twist, and Adjoint matrix, Screw Theory for Rigid body motions
Week 4	Forward Kinematics using screw theory
Week 5	Jacobian, manipulability and singularity measures (THA1 due, THA2 posted)
Week 6	Redundancy Analysis and inverse kinematics algorithms

MODULE 2: Registration and Calibration Concepts

Week 7	Registration and Calibration introduction, Correspondence-based registration Concepts and Techniques
Week 8	Pivot and Hand-eye calibrations Concepts and Techniques (THA2 due, THA3 posted)
Week 9	SPRING BREAK
Week 10	Hand-eye calibrations
Week 11	Group Presentations of THA2

MODULE 3: Constrained Control and Virtual Fixtures

Week 12-13	Virtual Fixtures concepts and techniques, Tele-Operation, and Co-operation concepts (THA3 due, THA4 posted)
Week 14	Group Presentations of THA3
Week 15-16	Constrained Optimization-based Control (THA4 due, Group Presentations of THA4 at the Exam Date)