AE6356 Syllabus

Spacecraft Attitude Estimation and Control, 3 Graduate Credits

General Information

Description

Attitude representations, dynamics, estimation, and control. Spacecraft attitude sensors and actuators. Attitude determination and control topics applied to spacecraft and space missions. Special cases and applications.

Pre- &/or Co-Requisites

Undergraduate-level rigid body dynamics. For example, AE 2220 Dynamics or equivalent.

Many of the assignments require use of Matlab. While prior experience using Matlab is not required, familiarity with Matlab and numerical programming is assumed.

Course Goals and Learning Outcomes

Upon completion of this course, the student should be able to:

- Understand different attitude representations and convert between them
- Understand the principles of operation of common spacecraft attitude sensors and actuators, and model them in a feedback control system
- Estimate spacecraft attitude from sensor measurements using various methods
- Apply different algorithms to perform spacecraft attitude control
- Simulate spacecraft attitude motion and control system performance

Course Requirements & Grading

Assignment	Date	Weight (Percentage, points, etc)
Homework	6 total assignments due every 2 weeks	42%
In-Class Midterm Exam	Midway through semester	23%
Take-Home Final Exam/Project	Last week of class	35%

Extra Credit Opportunities

Extra credit assignments will be presented to the class on a case-by-case basis in addition to the regularly assigned work. Examples of possible extra credit assignments would be to re-work missed problems on the midterm, to work optional additional homework problems, write a report on a topic that is relevant to the class, etc. Please contact the instructor if you want to discuss possible opportunities for extra credit.

Description of Graded Components

Homework: Consists of 6 assignments which are due every two weeks throughout the semester. Each assignment contains 7 problems, and each problem is worth 1% of your final grade.

In-Class Midterm Exam: The midterm exam will be given approximately midway through the semester. It is an open-book, open-notes exam which typically consists of 3 problems to be worked within a class period.

Take-Home Final Exam/Project: The final exam is a Take-Home Project which has a 1-week time to completion. The final exam synthesizes all the elements of the course in a single spacecraft attitude design problem. The final project will be handed out approximately one week before the end of the semester and will be due on the final class day. The final project is completed individually without consultation with other students or persons outside of class.

Grading Scale

At Your final grade will be assigned as a letter grade according to the following scale:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Full credit is awarded for solutions that are correct and demonstrate an understanding of the concepts of the problem. Partial credit is given for solutions that, while incorrect, demonstrate some knowledge of the concepts. Final grades may be curved based on overall class performance.

Course Materials

Course Text

Required Text: Markley and Crassidis, Fundamentals of Spacecraft Attitude Determination and Control, Springer, 2014. Reading and homework will be assigned from this text.

Additional Materials/Resources

The following textbooks may be helpful as optional references for this course:

(1) Schaub and Junkins, Analytical Mechanics of Space Systems, 4th edition, AIAA, 2018.
(2) Hughes, Spacecraft Attitude Dynamics, Dover, 2004.

Course Website and Other Classroom Management Tools

Course materials will be posted online to Canvas (https://canvas.gatech.edu/). Course materials (e.g. recorded videos) will be available to both in person and distance learning sections. Important communications to the class will be sent through the Canvas system; please be alert to these messages. Students will be held responsible for any message or announcement that has been posted to the class for more than 24 hours.

We will be using Piazza for discussion outside of class. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com.

Course Expectations & Guidelines

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

Students are required to report any suspected violation of the Honor Code to the Instructor whether or not they were directly involved in the incident.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Attendance and/or Participation

Classroom attendance, either in person or remotely, is strongly encouraged but not required. Active participation is essential for understanding major concepts and contributing to the learning of others.

Absences related to personal illness or emergency, or career development (e.g. presenting a paper at a conference or scheduled job interview) are considered excused. Please contact the instructor as soon as you know of a schedule conflict if this applies to you. Please see the Institute Absence Policy - https://catalog.gatech.edu/rules/4/ for more information.

Collaboration & Group Work

Discussions with other students about how to solve homework problems are allowed and encouraged; however, all work turned in must be the student's own original work.

The use of outside references (e.g. textbooks) is expected and encouraged; when appropriate cite any referenced material that is used.

Use of homework solutions from prior semesters (if/when applicable) is not allowed.

The midterm and final exams are intended to measure the learning of individual students; therefore receiving assistance from individuals during exams is not allowed.

Stand-alone calculators are allowed during in-class exams, but smart phones and other electronic devices may not be used. On open book exams, Laptop computers and Tablets may be used for viewing notes only. Equations may not be programmed into calculators before exams. Additional details regarding exam content and rules will be provided prior to the exam.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

Homework assignments are due at the designated time using online submission on Canvas. Any assignment turned in after collection is late. Late homework assignments may be turned in during the advertised grace period (usually 48 hours) for half credit. Any homework turned in after this is not counted.

Students in a distance learning section will receive a standard 1-week delay on all assignment and exam due dates.

Excused absences (see above) may be a justification to receive an extension on an assignment or to re-schedule an exam. Please contact the instructor as soon as you know of a schedule conflict if this applies to you.

Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Student Use of Mobile Devices in the Classroom

Mobile Devices (laptop computers and tablets) may be used in class to enhance your learning experience, provided they are used in support of the class and are not a distraction to you or your classmates. Viewing materials unrelated to the class and doing homework in class is not allowed. Cell phones should be set to silent mode during class. If you must answer a phone call during class, please step outside so as not to disturb the class.

Additional Syllabus Components

Honesty:

The School of Aerospace Engineering values honesty and integrity of all members of our community. An important element of this value is the academic honor code.

Georgia Tech Honor Challenge Statement: I commit to uphold the ideals of honor and integrity by refusing to betray the trust bestowed upon me as a member of the Georgia Tech community.

Honor Code: http://policylibrary.gatech.edu/student-affairs/academic-honor-code#Article_I:Honor_Agreement

Well Being:

The School of Aerospace Engineering values the complete well-being of all members of its community, which includes professional, physical, spiritual, emotional, and social dimensions. There are numerous resources to support the health and well-being of all members of our community: https://gatech.instructure.com/courses/108574

Mental Health Resources:

Emergencies: Can either Call 911 or call Campus Police at 404.894.2500 http://www.police.gatech.edu/
Center for Assessment, Referral, & Ed. (CARE): https://care.gatech.edu/ 404.894.3498 (Counselor On-Call)
Counseling Center: https://counseling.gatech.edu/ 404.894.2575
Stamps Health Services: https://health.gatech.edu/ 404.894.1420
Student Life and Dean of Students: https://studentlife.gatech.edu/content/get-help-now 404.894.6367
Victim-Survivor Support (VOICE): https://healthinitiatives.gatech.edu/well-being/voice 404-385-4464/(or 4451)
National Suicide Prevention Lifeline: 1.800.273.TALK (8255)
Georgia Crisis and Access Line: 1.800.715.4225

Social Justice:

The School of Aerospace Engineering values social justice for all members of the Georgia Tech community and the larger society. Social justice means that everyone's human rights are respected and protected. We stand committed in the fight against racism, discrimination, racial bias, and racial injustice. Our shared vision is one of social justice, opportunity, community, and equity. We believe that the diversity and contributions from all of our members are essential and make us who we are. We believe that our impact must reach beyond the classroom, research labs, our campus, and the technology we create, but must also improve the human condition where injustice lives. We will continue to work to understand, value, and celebrate all people and create an inclusive educational and work environment that welcomes all.

As a matter of policy, Georgia Tech is committed to equal opportunity, a culture of inclusion, and an environment free from discrimination and harassment in its educational programs and employment. Georgia Tech prohibits discrimination, including discriminatory harassment, on the basis of race, ethnicity,

ancestry, color, religion, sex (including pregnancy), sexual orientation, gender identity, national origin, age, disability, genetics, or veteran status in its programs, activities, employment, and admissions.

http://policylibrary.gatech.edu/equal-opportunity-nondiscrimination-and-anti-harassment-policy

Course Schedule

The following outline lists the topics to be covered in the course and tentative dates for exams. Changes to the outline will be discussed in class, and updated versions will be uploaded as necessary to Canvas.

Lecture	Topic	Homework
1	Introduction	H1 assigned
2	Euler's Theorem	
3	Quaternions	
4	Rodrigues Parameters	
5	Attitude Rates	H1 due, H2 assigned
6	Star Sensors	
7	Magnetometers	
8	Magnetic Control	
9	Matlab Simulations	H2 due, H3 assigned
10	Gravity Gradient Dynamics	
11	Gravity Gradient Stabilization	
12	Momentum Management	
13	Midterm Review, Q&A	H3 due
14	**Midterm Exam in class**	
15	Momentum Wheels and CMGs	H4 assigned
16	Wahba's Problem	
17	Attitude Kalman Filter	
18	Gyroscopes	
19	Attitude Kalman Filter Example	H4 due, H5 assigned
20	Single Input Single Output (SISO) Attitude Control	
	Spring Break – no class	
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21	Linear Quadratic Regulator (LQR) Attitude Control	
22	Nonlinear Controllers	
23	Constrained Attitude Pathfinding	H5 due, H6 assigned
24	Phase Plane Analysis	
25	Nonlinear Thruster Control	
26	Special Topic	
27	Final Project Handout, Q&A	H6 due, Final Project Assigned
28	**Work on Final Project – no class**	
29	**Final Project Due***	Final Project Due

*The Final Project will be due during the 'Final Instructional Class Days' unless otherwise announced by the instructor.