University Of California, Berkeley
Department of Mechanical Engineering

MECENG 136 and MECENG 236U – Dynamics and Control of Autonomous Flight (3 units)

Syllabus

CATALOG DESCRIPTION

This course introduces students to the dynamics and control of autonomous flight, with a focus on uninhabited aerial vehicles (UAVs). The course will cover modeling and dynamics of aerial vehicles, and common control strategies. The dynamics of a rigid body in three-dimensional space is studied in detail from first principles, and this is used to understand free flight, and the principles of operation of various sensors. This course is complemented by laboratory courses – a simulation course ME136SL/ME236SL, and a hardware laboratories in ME136HW/ME236HW. Although it is not required, students are encouraged to enroll in one of the lab courses. The hardware lab aims to provide hardware experiments corresponding to the theory provided in this course, and students work in teams for the hardware labs. The simulation labs provide a virtual version of the hardware labs, and students may work either alone or in teams in the simulation labs.

COURSE PREREQUISITES

ME132 (or equivalent, OK if taken simultaneously)

Recommended: Dynamics (e.g. ME104 or similar)

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Instructor-provided text will be made available online, which will serve as reference throughout the semester.

COURSE OBJECTIVES

Introduce the students to analysis, modeling, and control of unmanned aerial vehicles. Lectures will cover:

- Main forces acting on a UAV, including aerodynamics of propellers
- The kinematics and dynamics of rotations, and 3D modeling of vehicle dynamics
- Typical sensors, and their modeling
- Typical control strategies, and their pitfalls
- Designing a flight controller

DESIRED COURSE OUTCOMES

At the end of the course, students are able to:

- reason about the dominant effects acting on a UAV
- explain and derive dynamic relationships governing UAV flight
- explain different sensors available on a UAV

TOPICS COVERED

- Principle forces acting on a UAV, including aerodynamics of propellers
- The kinematics and dynamics of rotations, and 3D modeling of vehicle dynamics
- Typical sensors, and their modeling
- Typical control strategies, and their pitfalls
- Designing a flight controller

CLASS/LABORATORY SCHEDULE

Three hours of lecture and one hour of discussion per week..

OFFICE HOURS

There will be weekly office hours with the instructor, as well as with the GSI. Exact time will be scheduled in coordination with students.

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

Students become comfortable working with an advanced robotics system, and related computer tools. Students can reason about practical considerations relating to constrained systems such as UAVs.

RELATIONSHIP OF THE COURSE TO ABET PROGRAM 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
(g) an ability to communicate effectively
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

- Homework problem sets [30%]
- Midterm exam [30%]
- Final exam [40%]

Homework sets are due approximately every second week.

LATE SUBMISSION POLICY
Late submissions will be penalized 20 percentage points if late less than eight hours, and 10 additional percentage points for each additional late hour (or part thereof).

SAMPLE OF WEEKLY AGENDA

1 Introduction to UAVs

2 Introduction to programming the system I

3 Aerodynamics of a thin aerofoil, propeller dynamics

4 Modeling of 3D rigid bodies

5 3D Kinematics

6 3D Dynamics (Newton-Euler equations), inertial sensors

7 Introduction to estimation

8 Dynamics of UAVs

9 Control and stabilization: computing an equilibrium, linearization

10 Nested control loops, separation principle

11 Trajectory generation and tracking

12 Rotation formalisms: rotation matrix, rotation vector, and quaternions

13 Dynamics of unforced rotations

14 Comparison of different vehicle designs: helicopter / fixed-wings

ROOM SHARE AND GRADUATE CONTENT
The graduate-level version of the course will have a stronger emphasis on scientific method and advanced modeling techniques, as compared with the undergraduate-level course sharing the same room. Graduate students will have additional homework problems in the graded homework sets; these problems will have a deeper theoretical component, and students will be expected to be able to prove statements about dynamics. The exam questions for the ME236U students will be different than those for the ME136, especially requiring a deeper ability to derive results from first principles, and prove fundamental statements.

ATTENDANCE AND ACADEMIC HONESTY
Student are encouraged but not required to attend every lecture. Lectures will (as far as feasible) be recorded and made available in a timely fashion. All students should be familiar with the Code of Student Conduct and know that the general rules and student's rights stated in the document apply to this class (see http://uga.berkeley.edu/SAS/osc.htm).

DISABLED STUDENTS' PROGRAM (DSP)
If you have DSP accommodations, please contact the instructor immediately and communicate with discussion leaders. The Disabled Student's Program (260 César Chávez Student Center #4250; 510-642-0518; http://dsp.berkeley.edu) serves students with disabilities of all kinds. Services are individually designed and based on the specific needs of each student as identified by DSP's Specialists.

PERSON(S) WHO PREPARED THIS DESCRIPTION
Mark W. Mueller, 2023-08-22

ABBREVIATED TRANSCRIPT TITLE (19 SPACES MAXIMUM): INTRO CNT UNMND VEH
TIE CODE: LECS
GRADING: Letter
SEMESTER OFFERED: Fall
COURSES THAT WILL RESTRICT CREDIT: None
INSTRUCTORS: Mueller
DURATION OF COURSE: 15 Weeks
EST. TOTAL NUMBER OF REQUIRED HRS OF STUDENT WORK PER WEEK: Varies
IS COURSE REPEATABLE FOR CREDIT? No
CROSSLIST: None