Spacecraft Dynamics, 2023/2024

Rafael Vázquez Valenzuela
Julio Sánchez Merino

Departmento de Ingeniería Aeroespacial
Escuela Superior de Ingenieros, Universidad de Sevilla
rvazquez1@us.es

October 9, 2023

Main Goals

- Attitude representation for spacecraft (also applicable to aircraft!).
- Attitude determination (static estimation) of spacecraft attitude (also applicable to aircraft!).
- Attitude kinematics for spacecraft (also applicable to aircraft!).
- Attitude dynamics.
- Attitude estimation (dynamic estimation: filtering) of spacecraft attitude (also applicable to aircraft!).
- Passive and active stabilization of spacecraft attitude. Tracking.
- In addition: improve knowledge of estimation/control/optimization and its application to spacecraft.
- Matlab/Simulink/STK examples for simulation and/or resolution of spacecraft attitude estimation, control and optimization.

Lessons

1. Introduction.
2. Attitude representation.
   - Basic concepts. Representations. Interpolation. Matlab/STK representation (optional lab 1).
3. Attitude determination.
   - Sensors, TRIAD and Q methods. Matlab resolution (optional lab 1).
4. Attitude kinematics.
   - Attitude kinematics for attitude representations. Matlab simulation (optional lab 2).
5. Attitude dynamics.
   - Euler equations. Stability. Inertia wheels. Energy sink method. Gravity gradient. Matlab/STK simulation (optional lab 2).
6. Attitude estimation.
   - Filtering. Kalman Filter. Matlab simulation (mandatory lab 3).
7. Passive attitude control.
   - Spin stabilization. Yo-yo device. Stabilization with gravity gradient.
8. Active attitude control
   - Actuators. Linealization and some basic control methods. Tracking. Optimal control. Matlab simulation (mandatory lab 4).

Spacecraft dynamics labs

Two types:

- First half: visualization and computation labs, attitude kinematics and dynamics with Matlab; complementary to the subjects. Optional.
- Second half, the labs are central and mandatory:
  1. Kalman Filtering
  2. Attitude control

- Labs will be carried out:
  1. First half: Centro de Calculo or Classroom with student laptops outside class hours. Use of Matlab/STK.
  2. Second half: Centro de Cálculo or Classroom with student laptops outside (or perhaps in) class hours. Use of MATLAB mainly.

Spacecraft dynamics labs

- The first half labs, if carried out, will have a weight of 20% with regards to 90% exam if carried out (yes, the grade can surpass 10). If not carried out, 100% is the exam grade.
- The second half labs are mandatory to pass the class, as it will be exclusively graded on a *single* homework.
- A personal interview can be carried out to avoid plagiarism. They can include a video presentation.
- Attendance to the lab is not mandatory but recommended and will be controlled.
- The professor in office hours will not, in any case, solve the exercises or verify code. At most, doubts from classroom or lab material can be clarified and hints may be given.

Office hours - Rafael Vazquez

- Office 8, Aerospace Engineering Departament. Phone: 954488148.
- Office hours:
  - Monday 10:30-12:30
  - Tuesday 10:30-12:30
  - Friday 11:00-13:00
- Outside office hours, the professor will try to help if possible or with appointment. Appointment is advisable even in the official office hours to avoid conflicts with other tasks.
- Questions will be answered by email (rvazquez1@us.es) or in the EV forum.
- Office hours can be attended online and/or in groups.

Office hours - Julio Sanchez

- Office 9, Aerospace Engineering Departament.
- Office hours:
  - Monday 11:00-12:30
  - Tuesday 11:00-12:30
  - Wednesday 11:00-12:30
  - Thursday 11:00-12:30
- Outside office hours, the professor will try to help if possible or with appointment. Appointment is advisable even in the official office hours to avoid conflicts with other tasks.
- Questions will be answered by email (jsanchezm@us.es) or in the EV forum.
- Office hours can be attended online and/or in groups.

Additional References

B. Wie
Space Vehicle Dynamics and Control.
AIAA, 2006.

P. C. Hughes
Spacecraft Attitude Dynamics.
Dover, 2004.

H. D. Curtis
Orbital Mechanics for Engineering Students.
Elsevier, 2008.

Additional References

- There are many other references: books and journal papers.
- See EV for some references.
- On demand the professors can give specific references according to students' interests.
- Since this subject requires a background in other disciplines (math, mechanics, statistics, control) other references can be given to cover formation gaps.

Evaluation

- To pass this class there are two ways:
  - Before the official exam: mid-term (90% exam and 20% problem or 100% exam) + homework (HW). Minimum grade: 5.0 or more on each.
  - Official exams: Traditional, but questions about labs (both halves) can and will be posed.
- For the first oficial exam (1ª convocatoria) the mid-term is "saved" if the HW is failed or not done, then the student does a fully theoretical exam for the second half and questions about labs can and will be posed.
- Additional credit: a student that already has a passing grade can ask for additional work to obtain additional credit.
- The second and third official exams (Sept and Dec) need to do the full exam regardless of the mid-term. Questions about labs can and will be posed.

Coordination with other subjects

- The notes have been adapted for coordination with the subject “Spacecraft systems.”
- Note there are some overlaps with “Fundamentos de navegacion aerea” however, be careful: the theory goes deeper.
- There is a full planning with proposed/temptative dates at the end of this presentation. This can be adapted to fit other students’ deadlines but contact the professors ASAP.
- The schedule is planned for the class to be finished before the end of the year. Make-up classes will be conducted online if possible, to try to keep to this schedule.