IIT TIRUPATI, 2023

ME529L, Attitude Estimation and Control

Welcome to my course on **Attitude Estimation and Control**. In this course, we are going to study the subset of the physical state of a rigid body which describes its orientation in space, namely its *attitude* (refer to Figure 1 for an illustration). The subject is very important for aerospace and submarine applications,

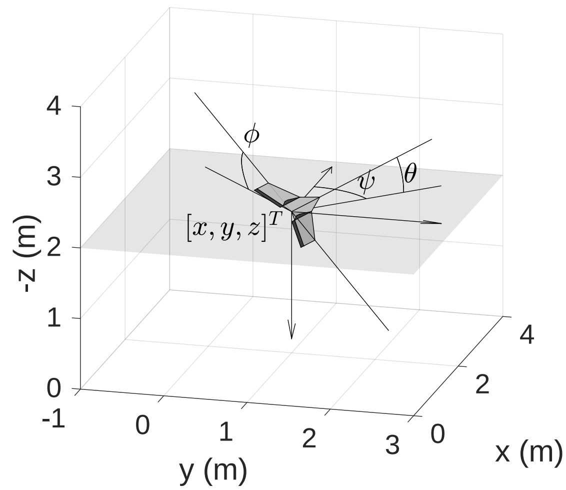

Figure 1: The *attitude* of a vehicle is the orientation it presents with respect to a fixed reference frame. In this figure, the position of the airplane is specified by the cartesian coordinates x, y, and z, while its attitude is specified by the Euler angles ϕ, θ, and ψ.

where vehicles move and rotate in 3 dimensional Euclidean space. The concepts are also useful in robotic applications with articulated joints that rotate about multiple axes.

Specifically, we shall look at

1. Euler's rotation theorem and the algebra of rotations;
2. Standard representations of attitude including Euler angles, orthogonal matrices, axis-angle representation, and quaternions;
3. Attitude kinematics and kinetics using the standard representations;
4. Geometric attitude estimation using Vector Triad, q-method and their numerical implementations;
5. Geometro-kinematic attitude estimation using extended Kalman filter and nonlinear complementary filters;
6. Linear attitude control using PID controllers for local stability and tracking;
7. Nonlinear attitude control using Lyapunov methods for Global stability and tracking.

At the end of this course, students are expected to be able to

1. Mathematically **represent the attitude** of a rigid body or collection of rigid bodies.
2. **Estimate rigid body attitude** using direction measurements and an optional angular velocity measurement.
3. **Control rigid body attitude** using local linear and global nonlinear methods

Classes are during the D slot period on Tuesday (10:00 to 11:00 hrs), Thursday (09:00 to 10:00 hrs), and Friday (11:00 to 12:00 hrs). The location will be announced on Google Classroom once it is finalized by the Academics section.

Your **final grades** in the course shall be computed as follows:

- 20% for homework.
- 20% for the first midterm test.
- 20% for a mini coding project.
- 40% for the final end-semester exam.

The homework could involve a substantial amount of **Matlab coding**. While it may seem cumbersome, I believe you are going to learn a lot when you actually write, test, and verify your own code, and compare it with the theory that you learn in class. You are all advised to familiarize yourselves with Matlab using Mathworks' online tutorials on Youtube:
`https://www.youtube.com/playlist?list=PL7CAABC40B2825C8B`

All homework assignments and solutions shall be posted on the course's Google classroom website.
https://classroom.google.com/c/NjEwNTYzODA1OTEw?cjc=t5cgoj2

I shall be using the following **textbook** for this course:
F. L. Markley and J. L. Crassidis, *Fundamentals of Spacecraft Attitude Determination and Control*, Springer, 2014.

Besides the above, you may find the following references useful:
D. Choukroun, Y. Oshman, J. Thienel, and M. Idan, *Advances in Estimation, Navigation, and Spacecraft Control*, Springer, 2015.
Y. Yang, *Spacecraft Modelling, Attitude Determination, and Control*, CRC Press, 2019.

And lastly, I expect all students to follow the student honour code, and abide by the Institute's academic honesty policy. Incidents of cheating and malpractice shall be reported to the Dean, and appropriate actions taken. That being said, I do not expect to have to resort to the above punitive measures in this class.