Course Take-Home Assignment 1

(AE4313)

A Practical Spacecraft Attitude Control System Design

(4 ECTS)

Introduction

This is the project assignment for the course on Spacecraft Attitude Dynamics and Control (AE4313). Students who wish to finish this course will have to complete this project. 4 ECTS will be issued to those who are able to finish the exercise successfully.

The specified problem is of practical considerations, when real attitude and angular velocity sensors are applied to the spacecraft attitude control system. The angular velocity sensors (rate gyros) are the type of sensors with unknown biases and very small measurement noises. The attitude sensors (sun sensors, horizon sensors) are the type of sensors with large measurement noise and free of biases. These sensors are widely used in spacecraft missions. Different types of sensor errors lead to attitude errors of the controlled spacecraft, when these sensors are directly applied to the attitude control system without any treatments. In practical applications, a state estimator (non-linear) can be applied to estimate the unknown bias of the rate gyro and filter out the measurement noise of the attitude sensor. The performance of the attitude controller will be improved very much by applying the state estimator.

The goal of this assignment is to design such an attitude control system with a state estimator in the closed loop system and to test the performance of the complete control loop. Comparisons of the two cases (with the state estimator and without the state estimator in the closed-loop system) should be performed as well. **This project has to be done individually**. You are not allowed to use AI tools to generate text for the report.

The report and the associated code that was used to generate the results in the report should be submitted on Brightspace not later than **June 8th 2025**. The reports should be in PDF form, the code should be collected in a zip-file. Any coding language is allowed.

Spacecraft Specifications:

Spacecraft orientation:	Nadir pointing
Spacecraft orbit:	Circular, 700 km orbit height
Attitude control type:	active three-axis control with ideal control actuators (no limit for the control torque)
Satellite inertia property:	$\begin{bmatrix} 2500 & 0 & 0 \\ 0 & 2300 & 0 \\ 0 & 0 & 3000 \end{bmatrix} \quad kgm^2$
Disturbance torques:	$T_d = [0.001 \quad 0.001 \quad 0.001]^T \quad Nm$
Available attitude measurements:	roll, pitch and yaw by sun and earth sensors
Angular velocity measurements:	three rate gyros
Attitude angle measurement errors:	pitch = 0.1^o std (white-normal noise) roll = 0.1^o std (white-normal noise) yaw = 0.1^o std (white-normal noise)
Angular velocity measurement errors:	x axis: 0.2^o/s (unknown bias only) y axis: -0.2^o/s (unknown bias only) z Axis: 0.15^o/s (unknown bias only)
Reference attitude angles:	0.0 degrees (roll) 0.0 degrees (pitch) 0.0 degrees (yaw)
Required attitude tracking accuracy:	0.1 degrees (roll) 0.1 degrees (pitch) 0.1 degrees (yaw)
Initial attitude errors:	10.0 degrees (roll) 10.0 degrees (pitch) 10.0 degrees (yaw)

Assignments:

1. Develop the complete spacecraft dynamics and kinematics equations for the three-axis-stabilised satellite ;

2. Design controllers (PD and/or PID) for roll-pitch-yaw control loops;

3. Simulate the performance of the controller with perfect attitude and angular velocity measurements without sensor noise and bias;

4. Simulate the performance of the controller with practical attitude and angular velocity measurements with noise and bias;

5. Design a structure of sensor integration in the case that the gyro noise is zero.

6. Design a state estimator (nonlinear) for this integration structure to estimate the unknown gyro biases and filter out the attitude sensor noises;

7. Integrate the state estimator in the spacecraft attitude control loop;

8. Simulate the performance of the complete spacecraft attitude control loop;

9. Compare the performances of the control systems with the state estimator and without the state estimator, and give adequate discussions;