Attitude Control Design

Attitude dynamics of an object is given by the following two sets of equations:

$$\dot{\boldsymbol{q}} = \frac{1}{2} \begin{bmatrix} -q_1 & -q_2 & -q_3 \\ q_s & -q_3 & q_2 \\ q_3 & q_s & -q_1 \\ -q_2 & q_1 & q_s \end{bmatrix} \boldsymbol{\omega} \tag{1}$$

$$I_{\text{moi}} \dot{\boldsymbol{\omega}} = -\boldsymbol{\omega} \times (I_{\text{moi}} \boldsymbol{\omega}) + \boldsymbol{M}_{\text{torq}} \tag{2}$$

Equation (1) is called kinematics equations because it describes the attitude/orientation change due to the angular velocity change in the body. Similarly, Equation (2) is called dynamics equations since it describes the angular velocity changes due to the applied torque/moment at the body. In Equation (1), a quaternion is used instead of conventional Euler angles to eliminate the singularity (i.e., gimbal lock) with respect to arbitrary rotations. A 3U cubesat in a 400 km circular orbit is considered for the project. Assume that the satellite is initially aligned with Local Vertical Local Horizon (LVLH) frame (or ram-nadir frame).

1. Graph the response of the satellite to a disturbance under torque-free condition. You can set your own initial condition for the attitude.

2. If the cubesat is spin stabilized, find the attitude trajectory along time by using quaternions.

3. Consider the gravity gradient torque for the attitude dynamics (Descriptions and derivations are in our text book). Find the attitude response of the satellite with respect to the disturbance. For this, we need to find the equilbrium status first.

4. Compare the simulation results with the stability analysis by linearization.

5. (Extra task 1 - Easy) If the cubesat is initially misaligned with LVLH frame, design the control torque M_{torq} that is able to align the satellite with LVLH frame by linearizing EOM.

6. (Extra task 2 - Not easy) Simulation of $\dot{\boldsymbol{B}}$ detumbling controller with an arbitrary initial angular velocity vector.

Guides on the report:
Please, submit the report electronically (Blackboard will be open). Late submissions will not be considered for grading. You should submit two files: the

report (PDF) and the zip file of executable MATLAB files (the main file must have the name "main.m"). File names for both PDF and MATLAB files must be 'AE426_Lastname_Firstname'.

1. 12pt, single space, standard 1 inch margin.
2. Clear steps of derivations of the each formula and explanation.
3. Equations must be clean and legible. All the quantities from the equation must be defined and consistent through the report.
4. Each figure must be smaller than a quarter of a page including captions.
5. There is no limit on the number of pages. Basically, what you wrote is what you know about the topic.
6. Write your report with MS Word and save it as PDF.