Spacecraft dynamics project plan and summary

Due date: 17th November, oral presentation on 18th November

November 1, 2017

Chapter 1

Problem description

Design a preliminary attitude control system for a satellite. The satellite can have any of the following stabilisation methods given below.

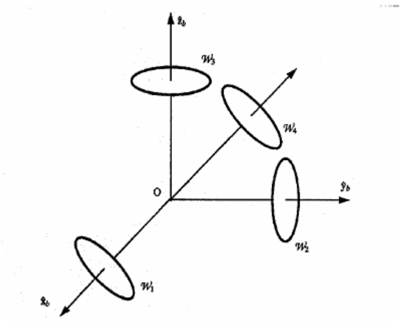
1. Gravity gradient stabilisation
2. Spin/dual spin stabilisation with passive/active magnetic torque for damping.
3. Momentum biased stabilisers with earth sensors measuring roll and pitch as primary sensors with gyroscopes and schemes for momentum dumping using thrusters.
4. 0 momentum biased spacecraft with star sensor for roll, pitch and yaw euler parameters with gyroscopes along with momentum dumping mechanism of wheels.

Steps involved:

1. Select a suitable kinematic system for spacecraft.
2. Using Euler's equation derive dynamical equations of motion and include gravity gradient torque.
3. Study stability dynamics of the system of both pitch motion and roll- yaw motion and figure out what kind of motion is possible. Also describe why active control system is required.
4. Design a control system accordingly to control spacecraft with PID strategies.
5. Figure out a control strategy to momentum dump with selected wheel based control.
6. Select proportional control gain accounting for maximum allowable steady state of 0.005 deg about all axes (for zero-momentum biased system).

7. Discuss possibility of integrating gravity gradient and spin/dual-spin parameters and ways to address passive/active nutation control if needed.

Problem Assigned:
Oceansat-1 is a 3-axis stabilized earth pointing satellite with a 4-wheel configuration which is traditional. That is the wheel configuration is with a wheel about each principal axis and the 4th wheel is mounted with 54.7 deg with respect to all three wheels. Nominally the principal axis wheels are rotated with 1000 rpm and the redundant wheel is rotated with -1732 rpm so that zero-momentum is achieved.



Configuration of energy/momentum wheels.

Figure 1.1: Configuration of wheels

The momentum dumping is achieved by using 60 Am^2 torque rods about all the three axes. Actual MI properties of the s/c after deployment are,

$$J_c = \begin{bmatrix} 1800 & -50 & -15 \\ -50 & 1600 & 25 \\ -15 & 25 & 1200 \end{bmatrix} Kgm^2 \tag{1.1}$$

Where the mass is given to be 1600 Kg, and [x,y,z] correspond to yaw, roll and pitch axes respectively.

Initially assume that the cross product of inertias is negligible and design the control system. Then when you actually apply the control, use the actual inertia matrix and compare and comment how the performance varies.

Use momentum dumping by torque rods about 2 axes and design PID control for $T_x = T_z = 2 * 10^{-3} Nm$ and $T_y = 10^{-4} Nm$ with $\omega_0 = 1.0741 * 10^{-3} rad/s$. Also compare strategy and time responses for tetrahedron and Pyramid configurations.

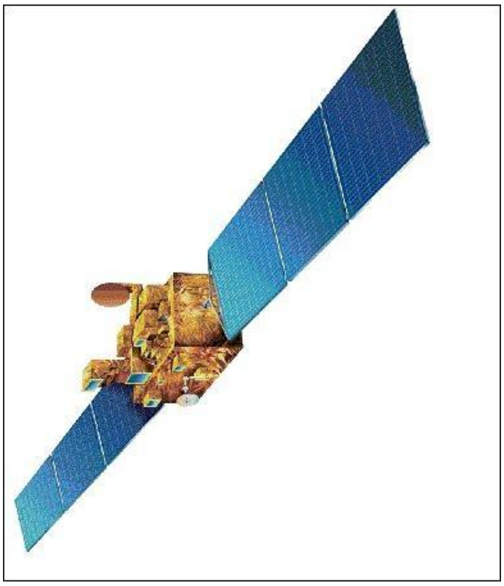


Figure 1.2: Ocean Sat

Here are the links for accessing data about Ocean Sat, particularly altitude, mass and trajectory.

1. `https://en.wikipedia.org/wiki/Oceansat-1`
2. `https://www.isro.gov.in/Spacecraft/oceansatirs-p4`
3. `http://www.vssc.gov.in/VSSC_V4/index.php/about-isro/missions/40-satellites-details/225-irs-p4-oceansat`
4. `https://eoportal.org/web/eoportal/satellite-missions/content/-/article/irsp4`
5. `https://www.nrsc.gov.in/OCEANSAT`

Chapter 2

Outline for project

In instructions, it is mentioned that the necessary criterion for report are the details of assumptions involved, kinematical equations, preferably based on Quaternions, dynamical equations and reason for control to meet steady state error, control system design with converged attitude error plots, and momentum dumping effects with final conclusions.

We need to refer chapters 4(for basics), Chapter 8(for momentum biased) in Sidi book. We may need material from other chapters and books too, due to the intricate nature of the material involved.

Here is a possible outline and a step by step methodology to execute the project.

- Model the satellite system in orbit and describe its orbit, attitude configuration and all the effects acting on the satellite, like a free body diagram.
- Develop a theoretical model of the zero momentum biased satellite taking all parameters into account from Sidi book.
- Account for the earth sensor and the gyroscopes and design so as to quantify and minimise attitude errors within the limits for earth sensors.
- Design the MATLAB code for momentum biased wheels only into account.
- Sophisticate the design by including the torque rods for control and using a pid system.
- Implement the MATLAB code to simulate the control and check if it attains the acceptable responses required.*
- Modify the system to a tetrahedral or Pyramid configuration and check for differences in control strategy and time responses.
- Include strategies in case one of the momentum wheels fail.
- Check for possibilities of gravity gradient/dual spin/spin stabilisation and required nutation control.
- Finally, summarise the points in a report along with the code and results and submit.

My suggestions involve that we create a sharing hub like Git-hub (preferably) or Google groups for the purpose of collaborating both on LATEX reports and MATLAB code. We can meet today afternoon in class for discussion of the same. Modelling the satellite system will be required to understand the project in detail for the group. It will be essential to study the Chapters in Sidi book for faster progress since it forms as the main crux. The earth sensor can be modelled separately along with the MATLAB code for momentum biased wheels and torque controls.

*-But the control simulation will require the earth sensor and gyroscope models. After attaining results, we can start compiling the report. Then we can modify the system and check for control differences and fail safe strategies. However, the time taken for control simulation will equal the time taken for modification of system and fail safe strategies and possible stabilisations each. Hence finishing the control simulation is paramount, so that the remaining portion of the project can be divided into 3 parts for completion.

Let me know what you think and your suggestions.