IIT Hyderabad

Peer Review

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Mechanical Engineering

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Group 2

Summary

The project report explores a passive attitude stabilization system for CubeSats that leverages Earth's magnetic field interaction with a permanent magnet embedded in the satellite. The goal is to maintain the CubeSat's solar panels aligned with the Sun throughout its orbit, specifically in a Sun-Synchronous Orbit (SSO) characterized by stable lighting conditions.

Technical Review

- Orbit selection: Sun-Synchronous Orbit at 500-800 km altitude with 97.5° inclination, providing consistent solar illumination.
- Passive magnetic torque theory: The CubeSat uses a permanent magnetic dipole moment m interacting with Earth's magnetic field B to generate a stabilizing torque T.
- The CubeSat body rotation and solar panel alignment are simulated in 3D using Rodrigues' rotation formula to model orientation changes.
- Conclusion: Passive magnetic stabilization with independently rotating solar panels is a low-cost, low-power, and effective solution for CubeSat attitude control, especially suitable for student or budget-constrained missions.

Questions

- How is Rodrigues' rotation formula applied to simulate the 3D orientation and rotation of the CubeSat and its solar panels?
- How does the simulation account for the dynamic variation of Earth's magnetic field along the orbit?
- How does the system handle energy dissipation or damping of residual angular velocities to avoid oscillations or instability?

Scoring: 9/10

Group 3

Summary

The project report proposes a satellite-mounted robotic arm system for deflecting small near-Earth asteroids (5–50 m diameter) via controlled momentum transfer.

Technical Review

- System Architecture: CubeSat base (1 m^3, 10 kg) with a 2-DOF robotic arm (1 kg arm + 1 kg wrist/gripper).Three reaction wheels (0.05 kg·m^2 each) for attitude control.Total pre-capture mass: 12 kg.
- Mathematical Modeling: Rigid-body dynamics for the satellite, arm, and asteroid.Quaternion-based attitude control with PD laws for reaction wheels.Angular momentum conservation during asteroid capture.
- Control System: Attitude control: Nonlinear PD control using reaction wheels.Arm control: Joint-level PD tracking for approach and capture.Momentum management: Desaturation strategies to avoid wheel saturation.

Questions

- How does the 2-DOF arm design balance simplicity with the need for dexterity in grasping irregular asteroids? What are the trade-offs vs. higher-DOF systems?
- The report assumes rigid-body dynamics. How would structural flexibility in the arm or satellite affect attitude control, and what mitigation strategies could be applied?

Scoring: 9.5/10

Group 5

Summary

The report titled "Insights into Docking of Chaser to Target Spacecraft" by Neeraj Balachandar, Shriram Hari, and Kevin D'Souza presents a detailed simulation and control framework for autonomous spacecraft docking operations. It integrates orbital mechanics, attitude dynamics, sensor-based navigation, and control theory to enable precise chaser spacecraft maneuvering relative to a target spacecraft in orbit.

Technical Review

- Problem Setup: The study models a chaser spacecraft attempting to dock with a target spacecraft in a circular orbit around a planet. The target maintains a stable orbit with constant angular velocity, while the chaser starts with different initial conditions and uses thrust vector control for maneuvering.
- Reference Frames: Three coordinate systems are used-Earth-Centered Inertial (ECI), Target Local Vertical/Local Horizontal (LVLH), and Target Body Frame-to describe positions and attitudes accurately.
- Attitude Dynamics: The spacecraft attitude is represented using quaternions, converted to Modified Rodrigues Parameters (MRP) for control purposes. Euler's rotational equations govern rotational dynamics, with control torques applied via PID controllers.

- The full 26-dimensional state vector includes positions, velocities, quaternions, and angular velocities for both spacecraft. The combined dynamics function computes state derivatives considering gravitational forces, relative motion, and control inputs.
- Conclusion: The integrated control and navigation framework effectively achieves autonomous docking under nonlinear relative orbital dynamics. The study lays groundwork for future extensions including robustness to disturbances and advanced control methods like Model Predictive Control.

Questions

- How would the control framework adapt if the target spacecraft is tumbling or performing non-cooperative maneuvers?
- How does the choice of controller gains affect the convergence speed and overshoot in both position and attitude control loops?

Scoring: 9/10

Group 6

Summary

The report "Precision Landing of a Post-Docking Descent System Using Model Predictive Control" by A. Padmaprabhan, Ashish Sam, and Sriram Babu presents a control framework for autonomous landing of a post-docking spacecraft modeled as a quadrotor-like system. It integrates nonlinear dynamics, feedback linearization, and Model Predictive Control (MPC) to achieve robust trajectory tracking under constraints.

Technical Review

- System Modeling: The spacecraft is approximated as a 6-DOF rigid body with quadrotor-like actuation. Dynamics are derived using Newton-Euler equations in body and inertial frames, incorporating blade element theory for thrust modeling and gyroscopic effects
- Feedback Linearization: Handles translational control (X, Y, Z) by generating reference roll , pitch , and thrust (U_1) commands.
- MPC for Attitude Control: Manages rotational dynamics using a Linear Parameter Varying (LPV) formulation, optimizing control inputs (U_2, U_3 , U_4) over a receding horizon.

Questions

- How does the controller perform under thruster failures or asymmetric mass distribution post-docking?

- Can the MPC formulation incorporate fuel-optimality criteria alongside tracking performance?
- What tuning methodologies are recommended for the PD gains in the virtual control inputs (v_x , v_y , v_z)

Scoring: 9.5/10

Group 7

Summary

The report "Skyhook" by Yashwanth, Ashwain Ganesh, and Harishankar explores a tethered satellite system (TSS) modeled as a dumbbell satellite for orbital transportation. It focuses on reducing fuel dependency by leveraging gravitational forces and rotational dynamics during mass loading/unloading operations.

Technical Review

- System Model: A three-mass dumbbell configuration (m_1 , m_2, m_b) connected by rigid, massless tethers. The state vector includes centroid position (r, θ) orientation angle ψ and their derivatives.
- Equations derived in polar coordinates using Newtonian mechanics, accounting for gravitational forces and rotational torques.Nonlinear coupled ODEs govern radial acceleration , angular acceleration, and spin dynamics.
- RK45 adaptive time-stepping used for numerical integration. Initial conditions assume circular orbits with zero radial velocity and scaled spin rates.

Questions

- How scalable is the RK45 method for larger TSS configurations with distributed masses?
- What is the critical tether length beyond which nonlinearities dominate, invalidating the current ODE structure?
- How does the system's energy efficiency compare to conventional rocket-based orbital transfer?

Scoring: 9/10

Group 8

Summary

The report "Attitude Dynamics and Control of a Nano-Satellite Orbiting Mars" by Vibhav presents a PD control framework for a Mars-orbiting nano-satellite tasked with three pointing modes: sun-tracking for power, nadir-pointing for science, and GMO-communication alignment. The work integrates orbital mechanics, reference frame kinematics, and attitude control theory.

Technical Review

- Mission Setup: A nano-satellite in Low Mars Orbit (LMO) at 400 km altitude must autonomously switch between three attitude modes:
  - Sun-pointing: Align solar panels with the inertial sun direction.
  - Nadir-pointing: Direct science sensors toward Mars' center.
  - GMO-pointing: Orient communication antenna toward a mothercraft in geosynchronous Mars orbit (GMO).
- MRP kinematics and Euler's rotational equations integrated using fourth-order Runge-Kutta.
- Control System: APD Control Law and Attitude Error: Computed via MRP and angular velocity between body and reference frames.

Questions

- What is the maximum allowable communication pointing error (in degrees) before data transmission fails?
- How does the fixed PD gain selection account for varying inertia during fuel consumption or payload deployment?

Scoring: 9.5/10