Modeling and Simulation of Single-Axis Satellite Attitude Dynamics in MATLAB

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Abstract

This project presents a simulation study of a single-axis satellite attitude control system using MATLAB. The simulation models the satellite's rotational motion under different torque inputs, including constant, noisy, and sinusoidal signals. The system's angular velocity and position responses are analyzed to understand the behavior under these inputs. The results demonstrate fundamental satellite dynamics and the impact of external disturbances and control strategies.

1. Introduction

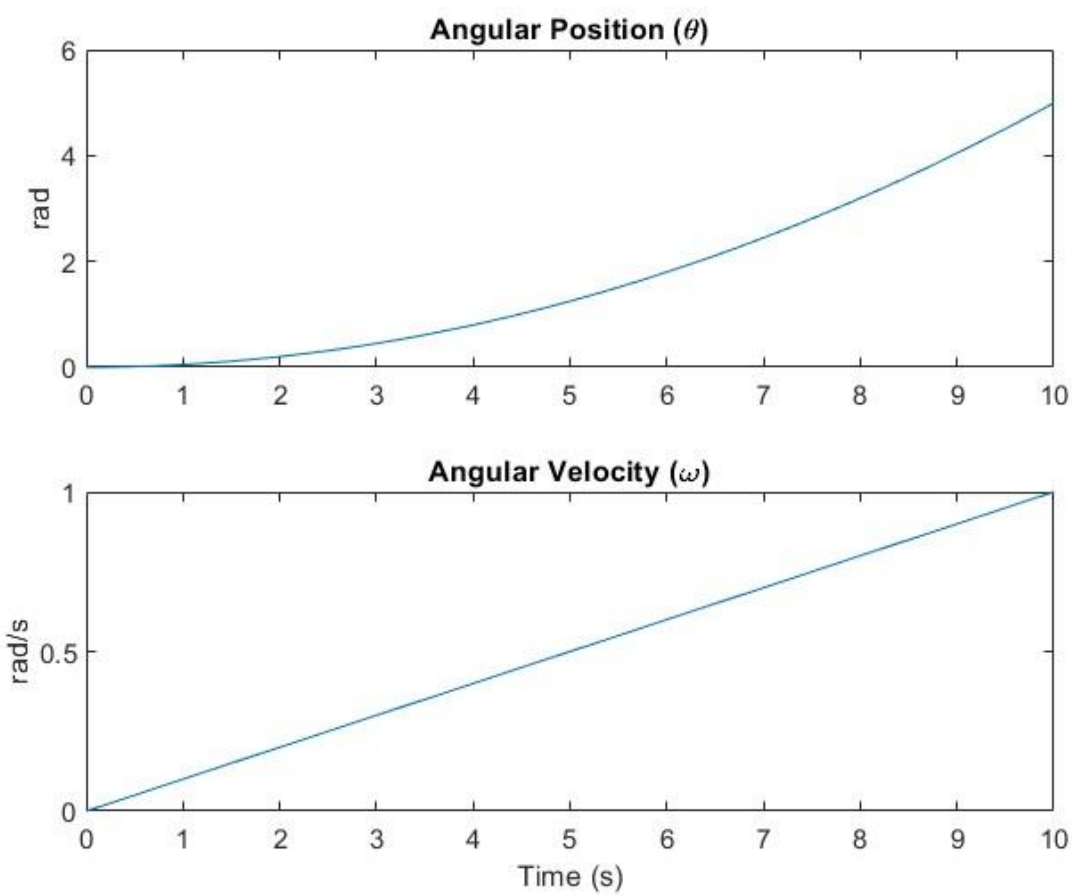
Satellite attitude control is essential for orientation management in space missions. This project models a simplified one-dimensional rotational dynamics of a satellite and simulates its response to various torque inputs. MATLAB is used as the simulation environment due to its efficiency in solving dynamic equations and visualizing system behavior.

2. System Model

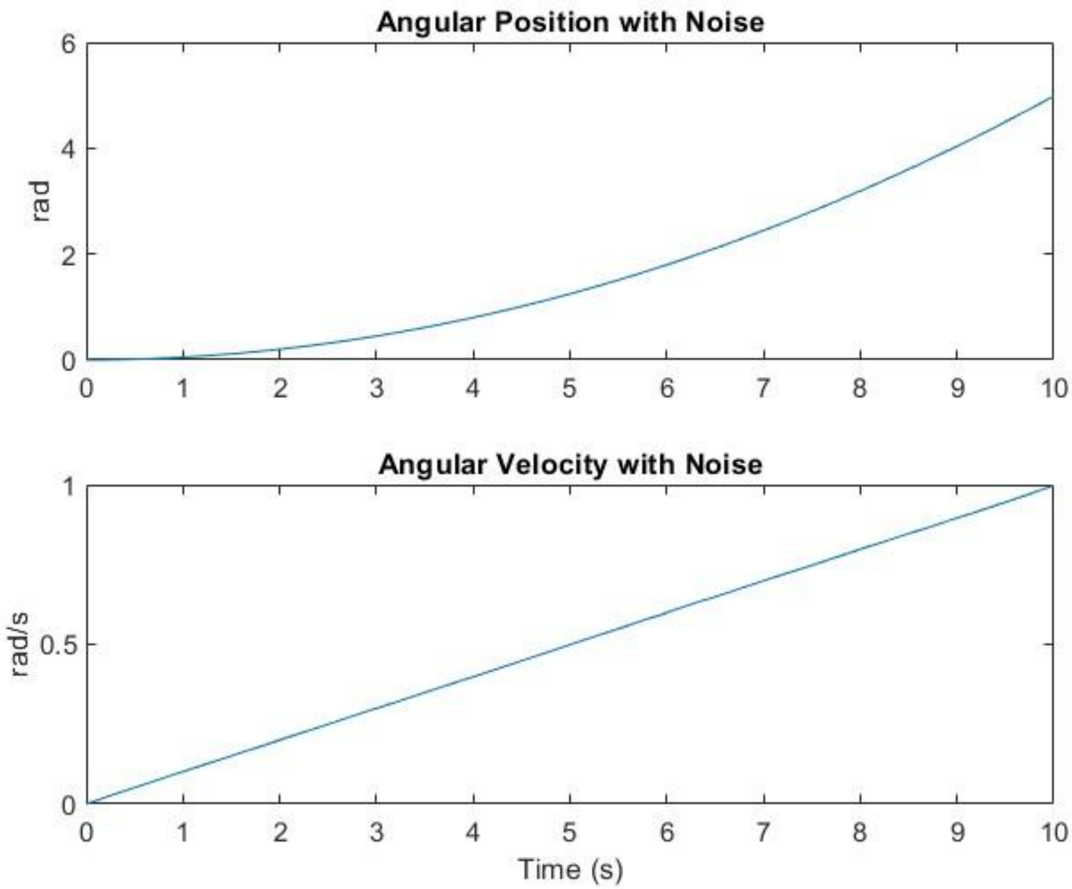
The satellite is modeled as a rigid body with a known moment of inertia J . The motion is governed by the rotational equation:

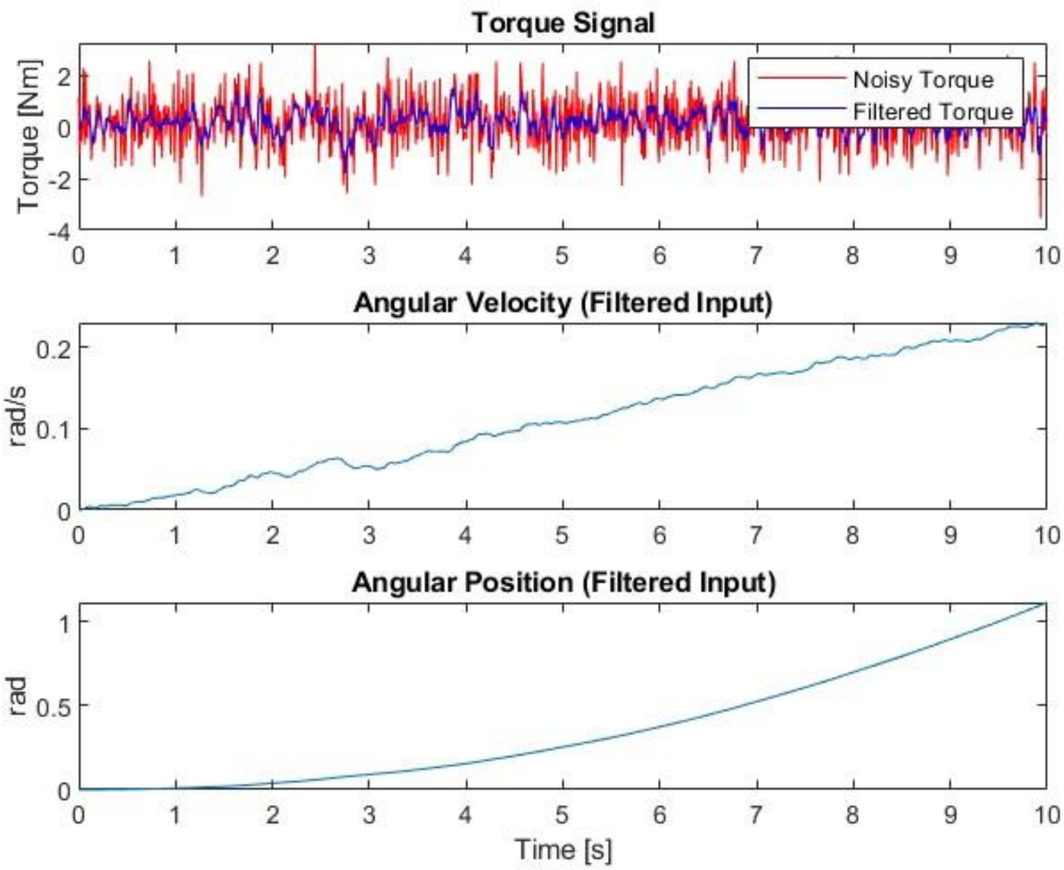
$$\alpha(t) = \frac{\tau(t)}{J}$$

where α is the angular acceleration and τ is the applied torque. Angular velocity ω and position θ are obtained using numerical integration (Euler method).

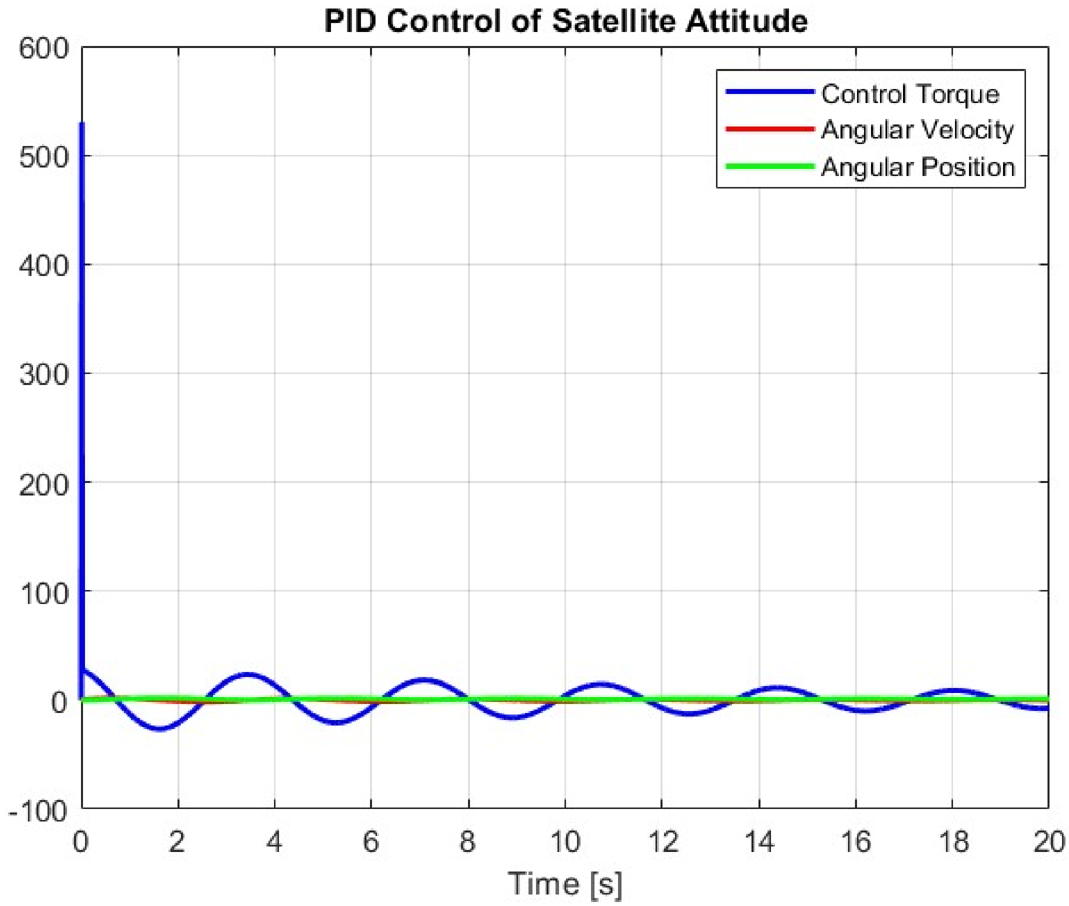


3. Simulation Scenarios

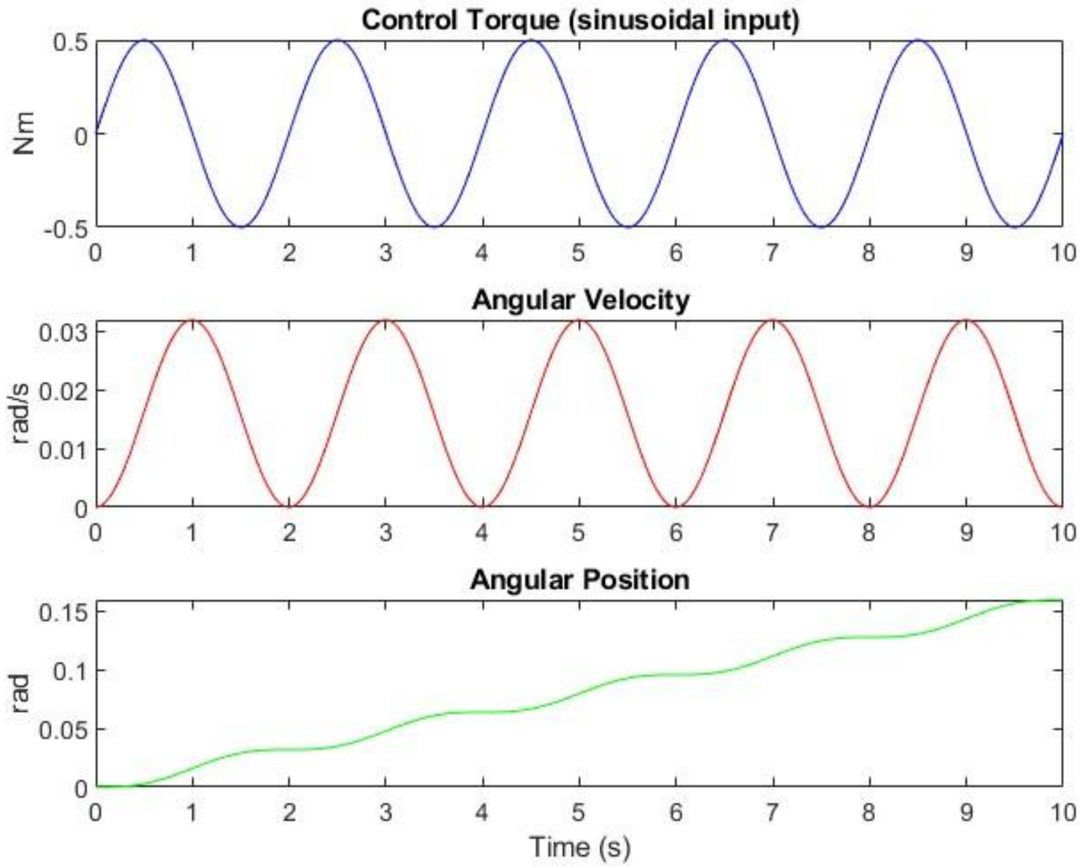




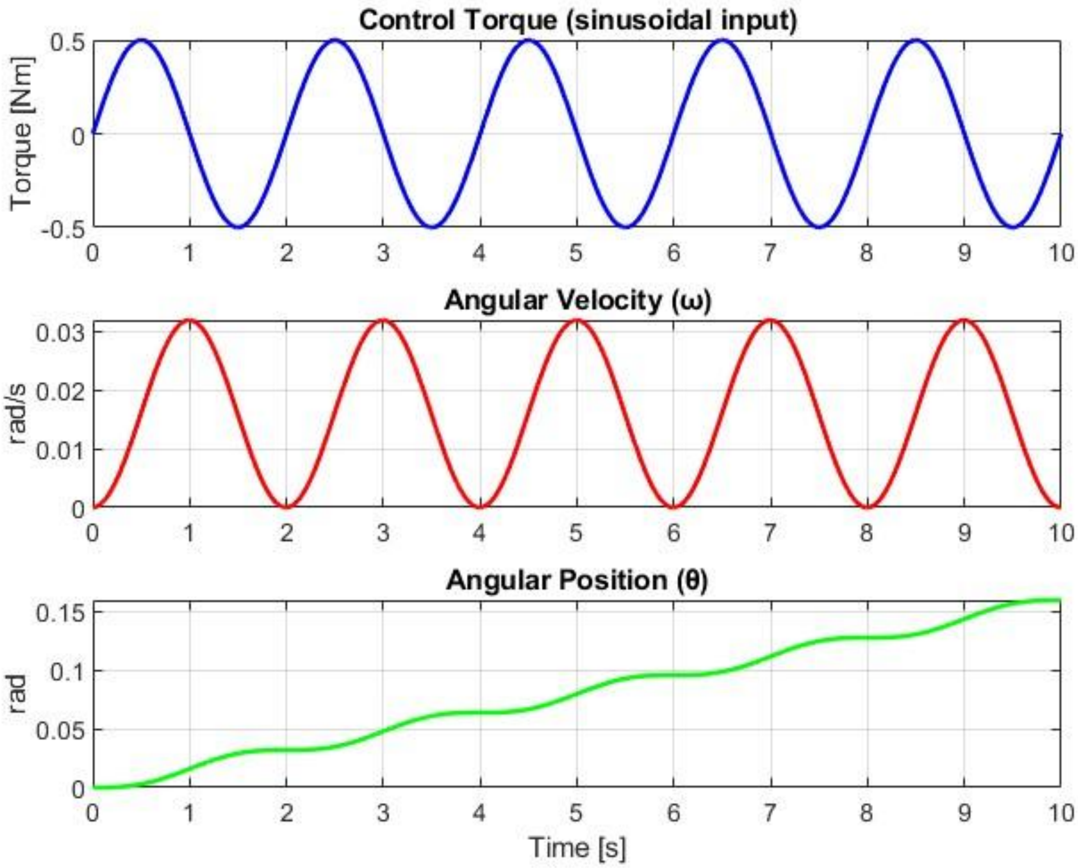
Torque Signal
Noisy Torque
Filtered Torque
Torque [Nm]
Angular Velocity (Filtered Input)
rad/s
Angular Position (Filtered Input)
rad
Time [s]

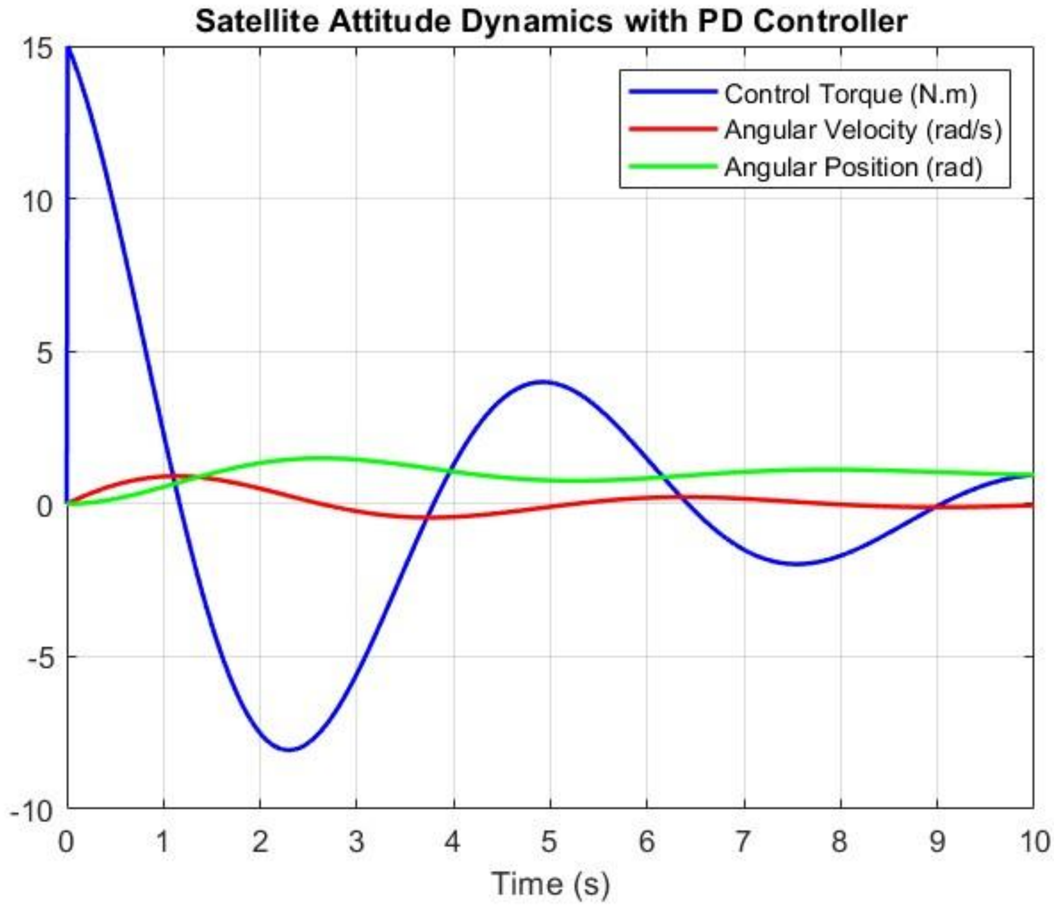


PID Control of Satellite Attitude
Control Torque
Angular Velocity
Angular Position
600
500
400
300
200
100
0
-100
0
2
4
6
8
10
12
14
16
18
20
Time [s]

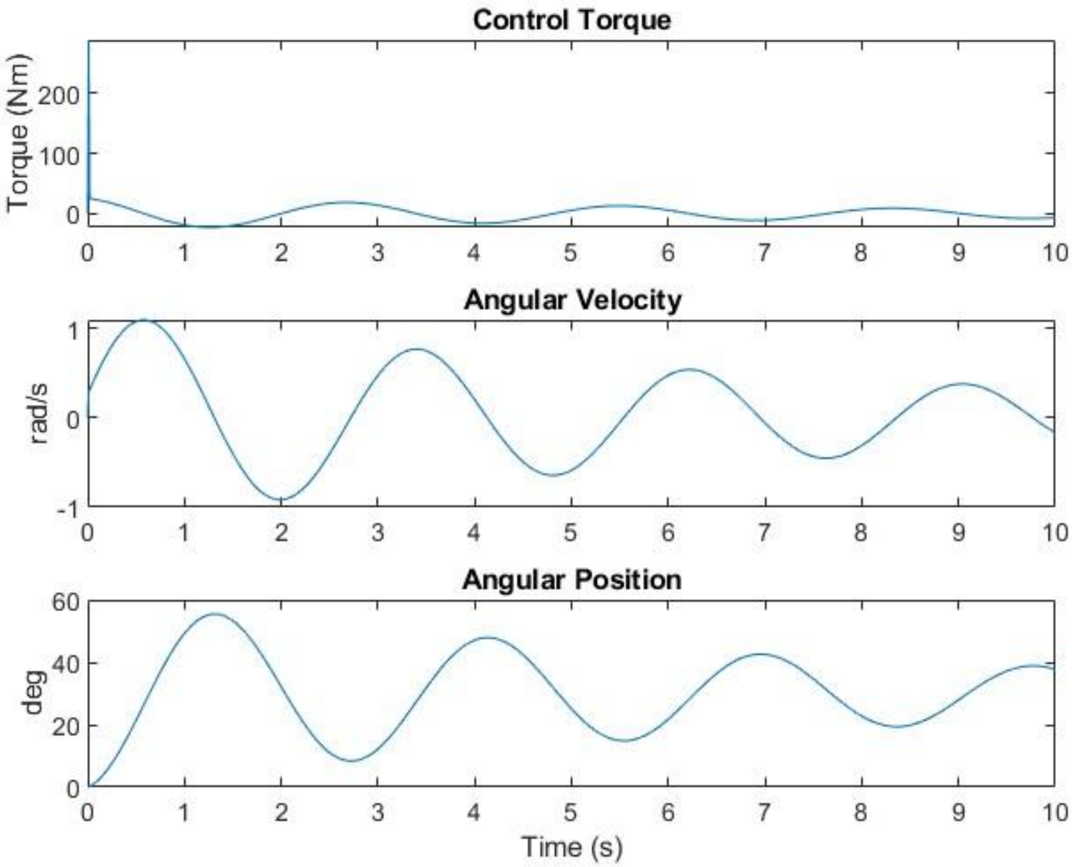


Control Torque (sinusoidal input)
Nm
0.5
0
-0.5
0 1 2 3 4 5 6 7 8 9 10
Angular Velocity
rad/s
0.03
0.02
0.01
0
0 1 2 3 4 5 6 7 8 9 10
Angular Position
rad
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10
Time (s)


Control Torque (sinusoidal input)
Torque [Nm]
0.5
0
-0.5
0 1 2 3 4 5 6 7 8 9 10
Angular Velocity (ω)
rad/s
0.03
0.02
0.01
0
0 1 2 3 4 5 6 7 8 9 10
Angular Position (θ)
rad
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10
Time [s]



Satellite Attitude Dynamics with PD Controller
Control Torque (N.m)
Angular Velocity (rad/s)
Angular Position (rad)
15
10
5
0
-5
-10
0
1
2
3
4
5
6
7
8
9
10
Time (s)


Control Torque
Torque (Nm)
200
100
0
Angular Velocity
rad/s
1
0
-1
Angular Position
deg
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10
Time (s)

4. Conclusion

The simulations illustrate the fundamental response characteristics of a satellite's attitude dynamics. The study highlights the importance of torque profiles on satellite motion and lays the groundwork for more advanced control strategies.

5. Future Work

- Future development may include:
- Multi-axis modeling
- Feedback control (e.g., PID, LQR)
- Nonlinear disturbance rejection
- Integration with sensor models (e.g., gyroscopes)