Model-Based PID Control for Stabilization and Trajectory Tracking of a Quadcopter

Description: This project focuses on the design and implementation of a model-based Proportional-Integral-Derivative (PID) control system for the stabilization and trajectory tracking of a quadcopter, which inherently exhibits unstable behavior. The quadcopter's dynamics are captured through a set of differential equations that consider its position, velocity, attitude, and angular velocity. The control system employs PID controllers to regulate these states and ensure stable flight.

Key Features:

- **Dynamic Modeling:** A comprehensive dynamic model is developed to describe the quadcopter's motion, accounting for position, velocity, attitude angles, and angular velocity.
- **PID Control:** The Proportional-Integral-Derivative (PID) control strategy is implemented to regulate the quadcopter's position and orientation. PID gains are tuned to achieve desired stabilization and trajectory tracking performance.
- **Desired State Tracking:** The quadcopter is tasked with tracking a predefined trajectory while maintaining stability. The desired trajectory includes position and attitude profiles, allowing the quadcopter to navigate a specific path.
- **Real-Time Visualization:** A real-time 3D plot provides an intuitive visual representation of the quadcopter's trajectory throughout the simulation.
- **Controller Performance Analysis:** The project evaluates the PID controller's performance by analyzing the quadcopter's response to various trajectory scenarios, assessing stability, accuracy, and efficiency.
- **Force and Moment Calculations:** Forces and moments acting on the quadcopter are calculated in both the inertial and body frames. These calculations are crucial for control input generation.
- **Simulation Results:** Simulation results are presented, showcasing the quadcopter's trajectory, position, velocity, forces, moments, and angular attitudes over time.
- **Future Enhancements:** The project outlines potential enhancements, such as integrating sensor feedback, considering aerodynamic effects, and applying advanced control strategies for improved performance.

Conclusion: This project demonstrates the successful application of PID control to stabilize and track trajectories for an inherently unstable quadcopter. By utilizing dynamic modeling and PID tuning, the quadcopter's response to external inputs is controlled, enabling precise navigation along predefined paths. The project lays the foundation for further research into advanced control techniques and practical implementation for autonomous flight and robotics applications.