Physics-Based Quadcopter Dynamics and Control Simulation

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Overview

This project presents a physics-based mathematical model and simulation of a quadcopter UAV using rigid-body dynamics. The simulator evolves from a minimal vertical motion model to a fully coupled 3D quadcopter with motor-generated torques and stabilization control. It demonstrates how thrust, torque, attitude, and feedback control interact to produce realistic drone motion.

Model Architecture

The quadcopter model follows the canonical dynamics chain: motor thrusts → torques → attitude → thrust vector → translation → trajectory.

Physics Components

Vertical Dynamics: $F = T - mg$

3D Translational Motion: $a = T/m + g$

Attitude Dynamics: $\tau = I\alpha$

Motor Torque Model: $\tau_{roll} = L(T2 - T4)$, $\tau_{pitch} = L(T3 - T1)$

Stabilization Control: $\tau = -k\theta$

Simulation Capabilities

• 3D quadcopter trajectory simulation
• Motor-induced rotational dynamics
• Coupled translation–rotation motion
• Stabilization via feedback control
• Trajectory visualization and animation

Results

The stabilized quadcopter model demonstrates realistic behavior: an initial tilt produces transient drift, followed by automatic leveling due to feedback control, resulting in a straightened trajectory. The simulation confirms expected quadcopter flight mechanics from first-principles physics.

Conclusion

This project implements a complete rigid-body quadcopter dynamics and control simulator. It integrates translational motion, rotational dynamics, motor torque generation, and feedback stabilization into a unified physics-based framework suitable for UAV research and control development.