

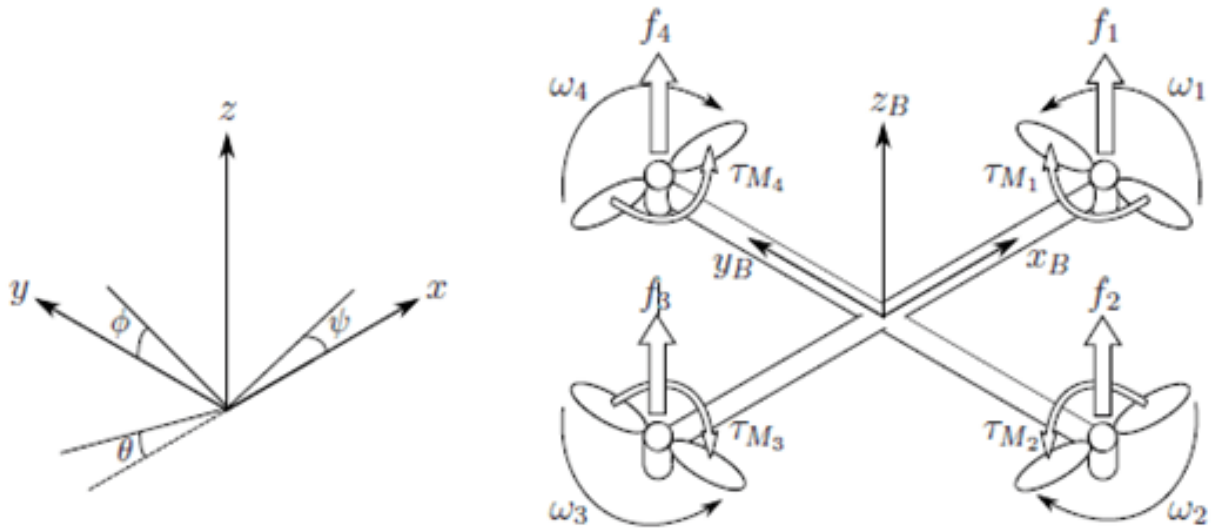
## THE ROLE OF CONTROL THEORY IN SPORTS AND DRONES

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Control theory, a cornerstone of engineering and applied mathematics, studies how systems can be directed using feedback to achieve desired outputs. Though it originated in fields like robotics and electrical engineering, its applications have since spread into diverse domains—including sports and aerial robotics like drones. This article explores how control theory shapes both the physical performance of athletes and the technological prowess of modern drones. At its core, control theory revolves around managing dynamic systems using inputs, feedback, and control algorithms. The system receives an input, reacts to it, and produces an output. This output is measured and compared with a desired target (called the setpoint), and any difference (called the error) is used to adjust the input in a feedback loop. This framework applies broadly—from thermostats regulating room temperature to self-balancing robots and precision-guided missiles. In both sports and drones, the key lies in using real-time data to make continuous adjustments that enhance performance. In sports, athletes function as complex biological control systems. Muscles act as actuators, joints function as mechanical linkages, and the brain operates as a control center, processing sensory inputs from eyes, ears, and proprioceptive systems to adjust movement on the fly. Athletes rely on both **feedforward** and **feedback** control. Feedforward control is used when a player swings a bat or kicks a ball based on prior experience and training. Feedback control kicks in when a tennis player adjusts their grip or stance after a shot based on ball trajectory or balance cues. Modern sports science uses control theory to model these responses, particularly in rehabilitation, where wearable sensors monitor joint angles, force, and timing. Coaches and physiotherapists can assess how an athlete's control system adapts after injury or training. Technologies such as EMG (electromyography) and motion tracking provide data for real-time analysis. Athletes can use this biofeedback to improve performance—training their nervous system to optimize timing, precision, and muscle coordination. In drones, control theory governs flight dynamics, stability, and navigation. A drone is a classic example of a closed-loop system, where sensors and controllers continually adjust the motor outputs to maintain desired behavior. Drones are equipped with sensors such as GPS, inertial measurement units (IMUs), gyroscopes, and accelerometers. These sensors feed data into onboard microcontrollers, which calculate necessary corrections to the propeller speeds. This allows the drone to hover, rotate, climb, or descend with precision.



Picture 1. Mathematical model of UAV

Maintaining stable flight in a dynamic environment (wind, obstacles, user input) requires continuous control adjustments. Proportional-Integral-Derivative (PID) controllers are commonly used to manage pitch, roll, yaw, and altitude. More advanced drones may employ Model Predictive Control (MPC) or adaptive control algorithms to handle uncertainty and optimize energy use. As drones evolve, control theory plays a critical role in enabling autonomous flight—such as obstacle avoidance, formation flying, and payload delivery. For example, delivery drones need to balance route efficiency with safety, requiring sophisticated control loops that account for GPS drift, object tracking, and sudden wind gusts.

#### Reference

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