Camera Drones
Lecture – Flight mechanics and Control

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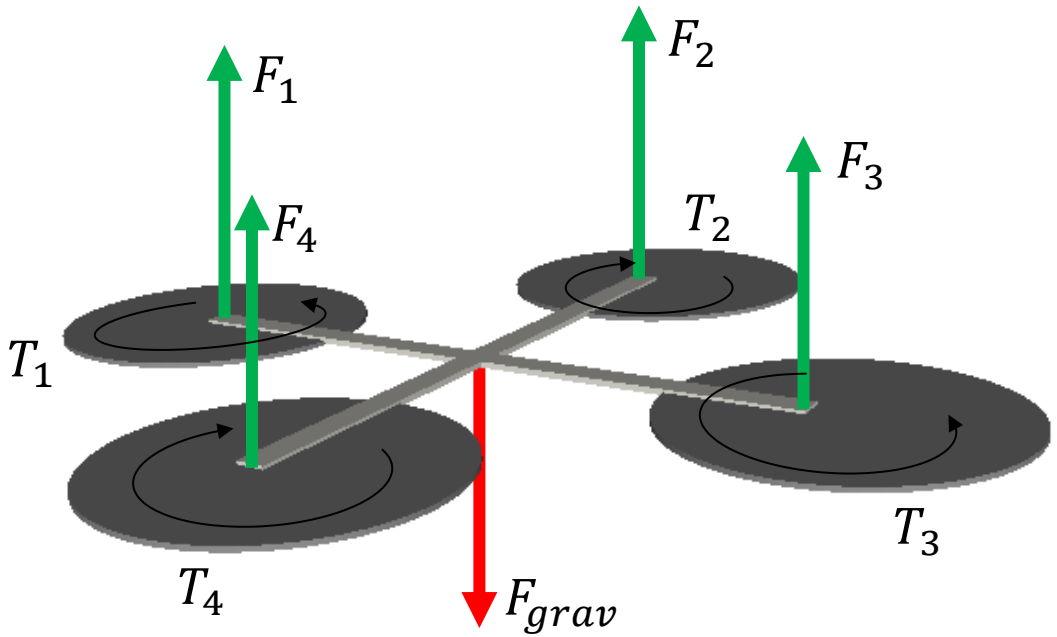
Outline

- Quadrotor flight mechanics
- Quadrotor control principles

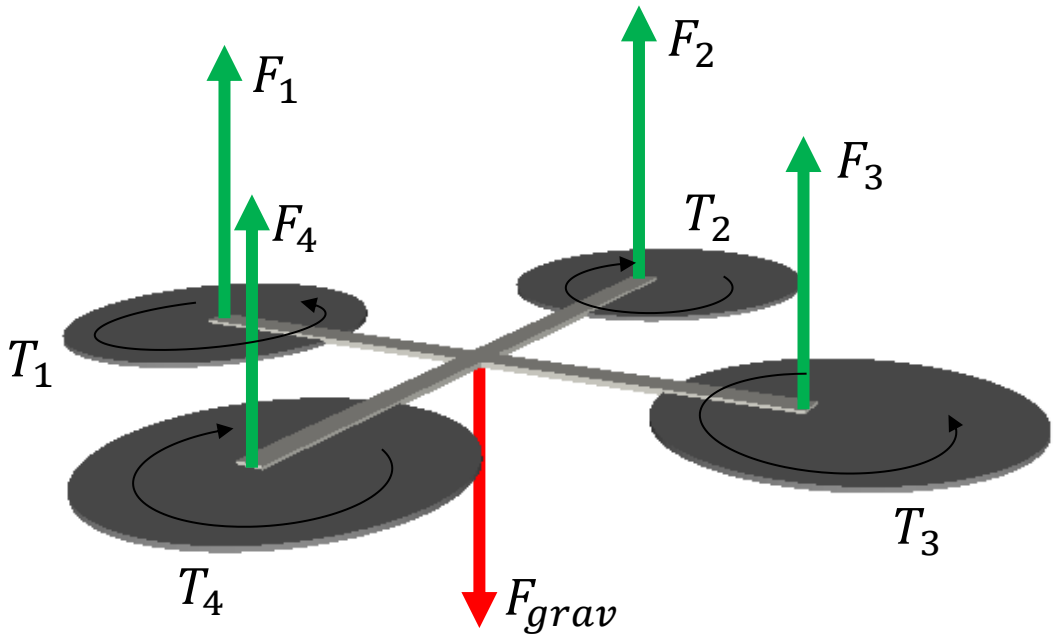
Quadrotor dynamics

- Each rotor produces force/lift and torque by accelerating air
- Gravity pulls quadrotor downwards



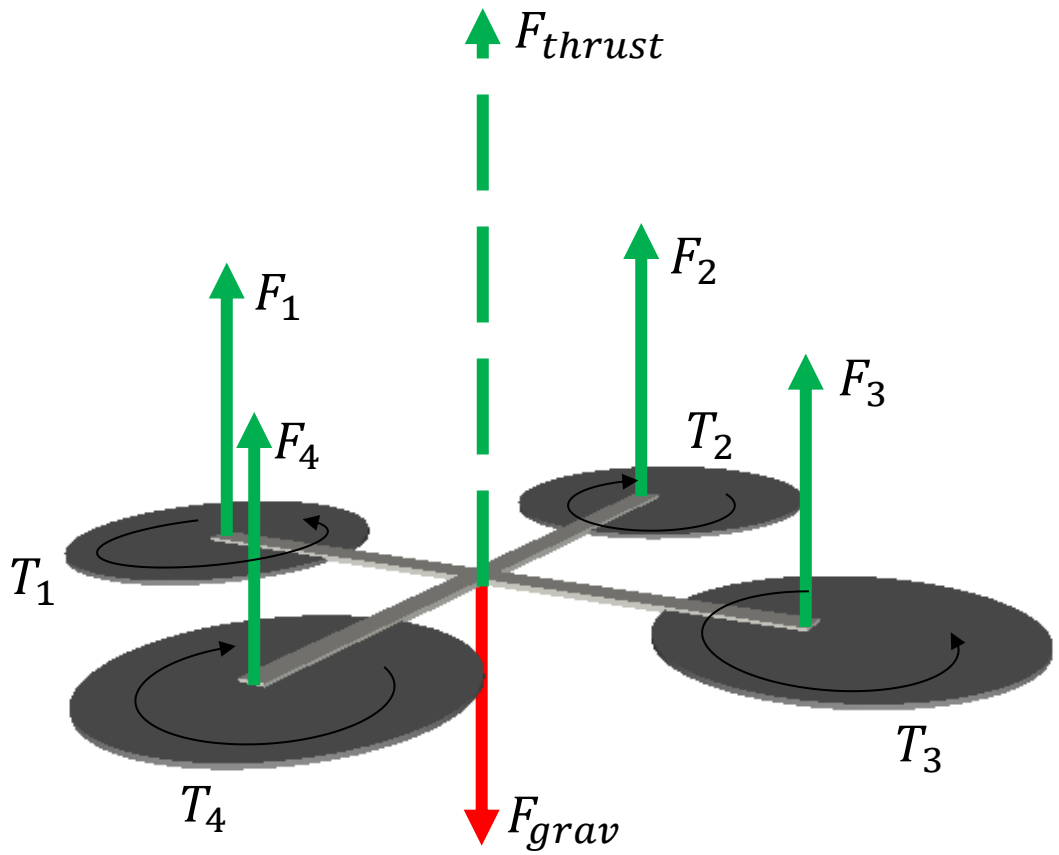
Quadrotor hovering

- Hovering when the lift exactly balances the gravity and when the torque is precisely canceled
- Torque is canceled by counter-rotating rotors



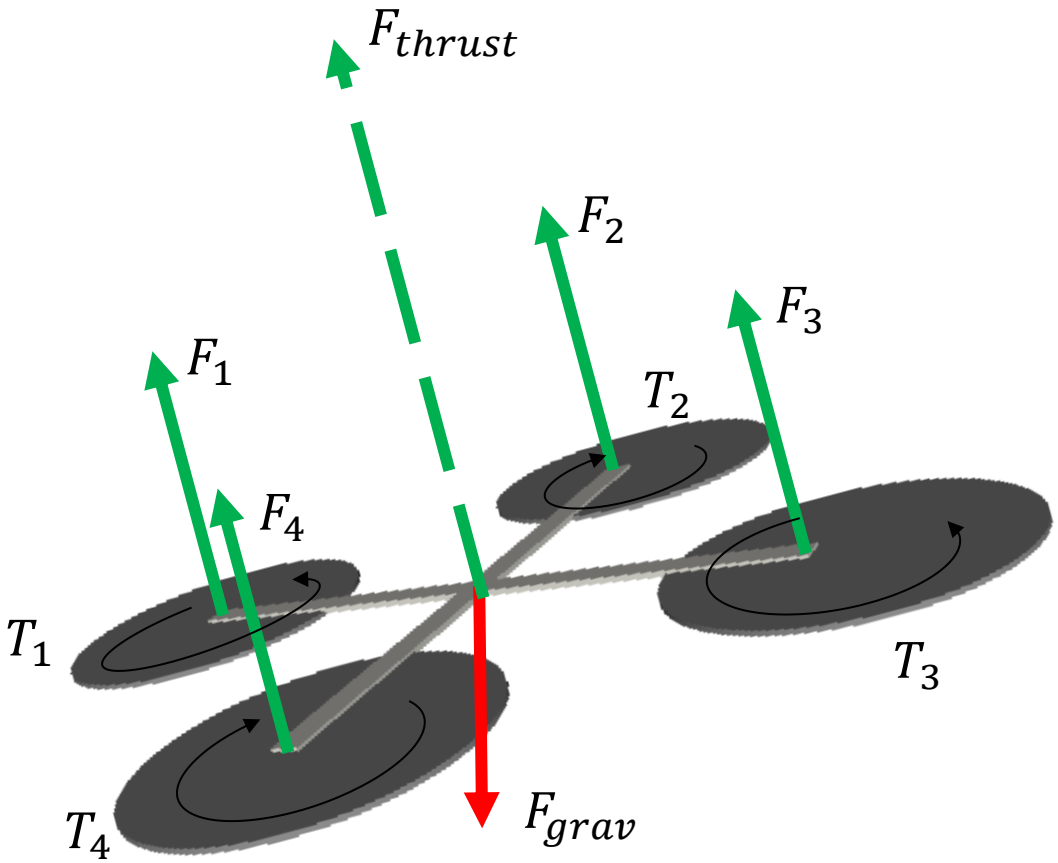
Quadrotor vertical acceleration

- Thrust $F_{thrust}=F_1 + F_2 + F_3 + F_4$



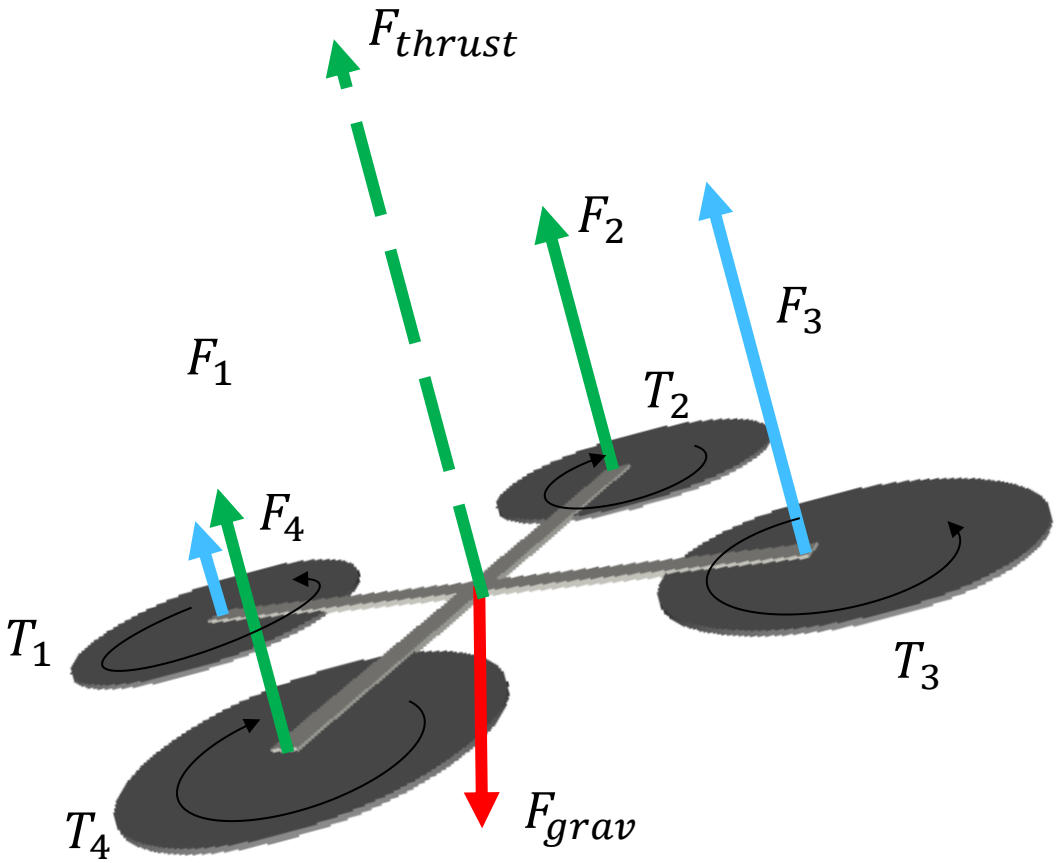
Quadrotor vertical and horizontal acceleration

- Thrust $F_{thrust}=F_1 + F_2 + F_3 + F_4$



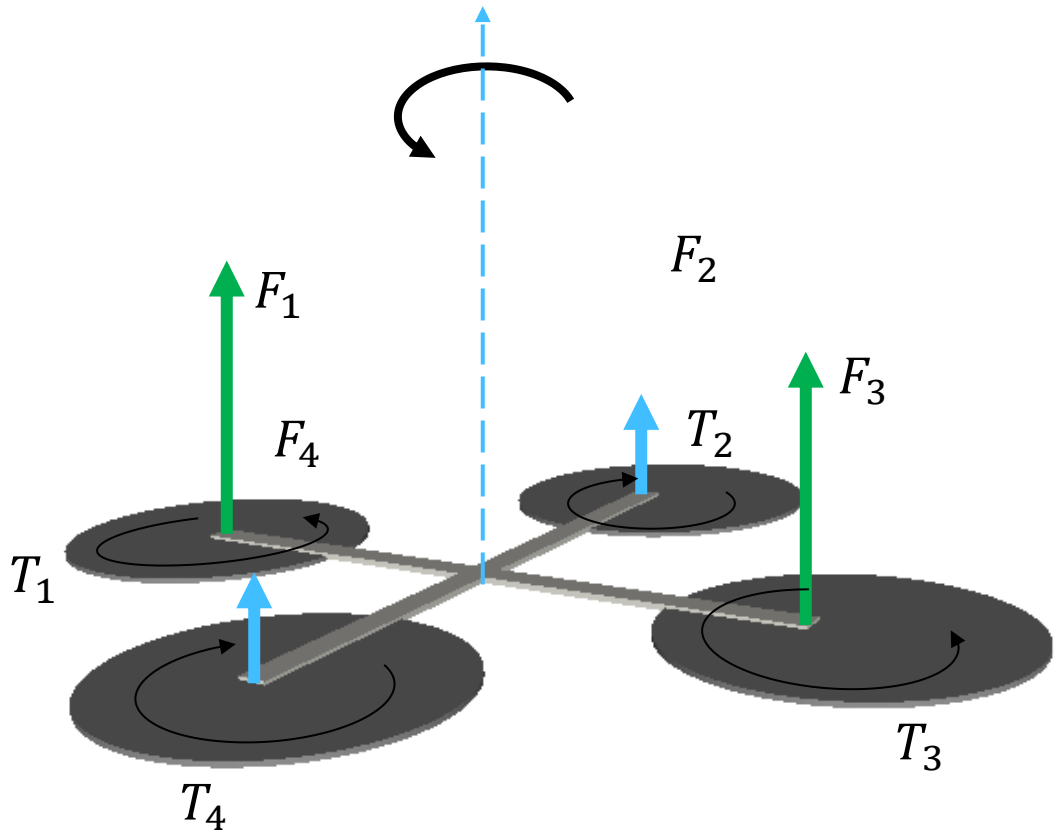
Quadrotor pitch and roll

- To pitch or roll the forces produced by the rotors need to be out of balance
- However, pure pitching and rolling not possible. Every pitch or roll induces also a horizontal acceleration



Quadrotor yaw

- Out-of balance torque is used to produce yaw rotation
- Torque $T = T_1 - T_2 + T_3 - T_4$
- Change rotor spin of pairs of rotors to keep the lift constant, but create imbalanced torque

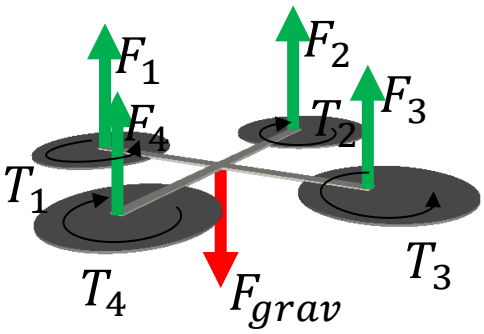


Outline

- Quadrotor flight mechanics
- Quadrotor control principles

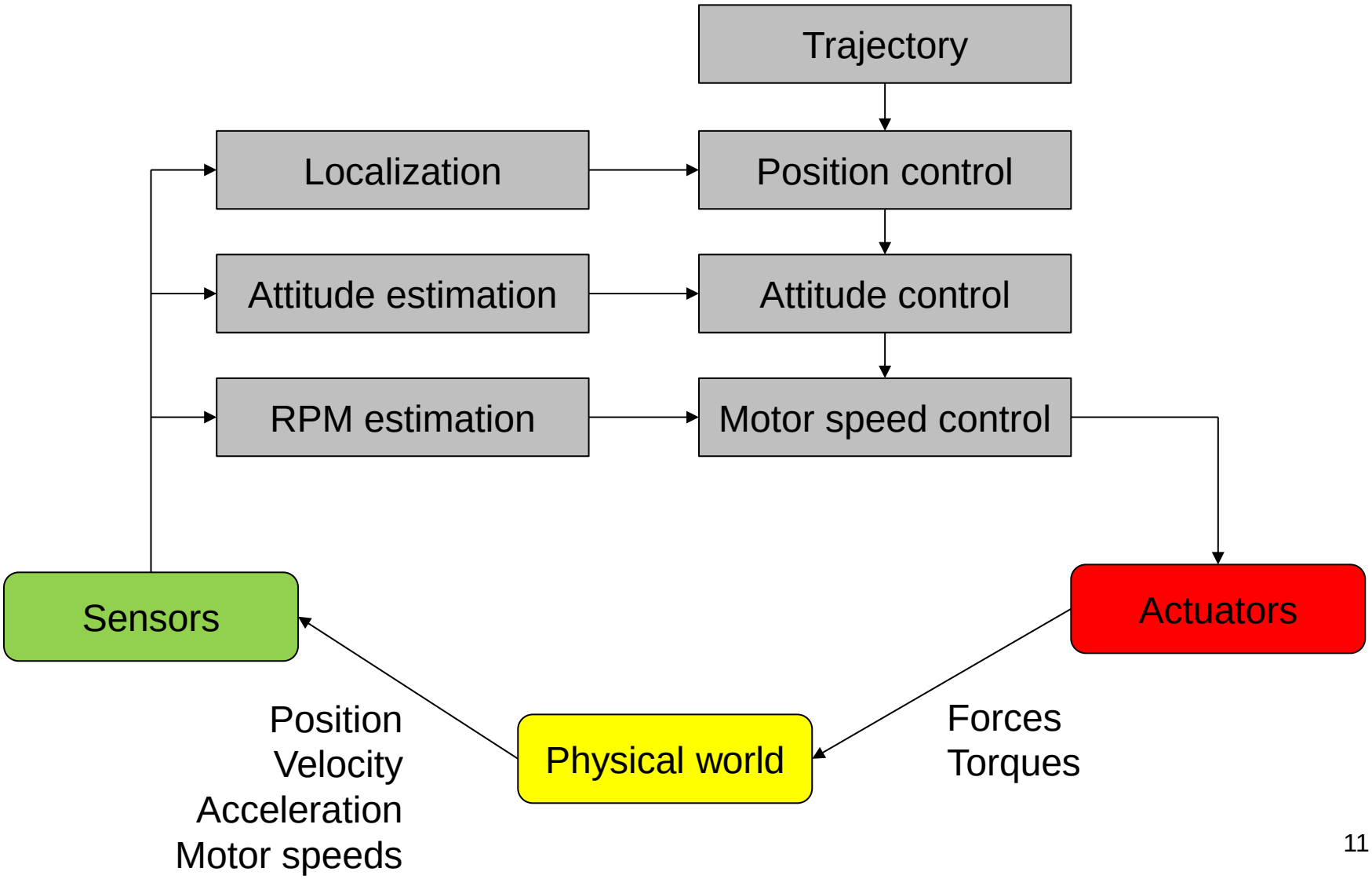
Quadrotor control - Hovering

- Hovering means quadrotor needs to hold position
- Requirement:
  - Each rotor produces exactly the same thrust
    (if there is a slight imbalance, a movement occurs)

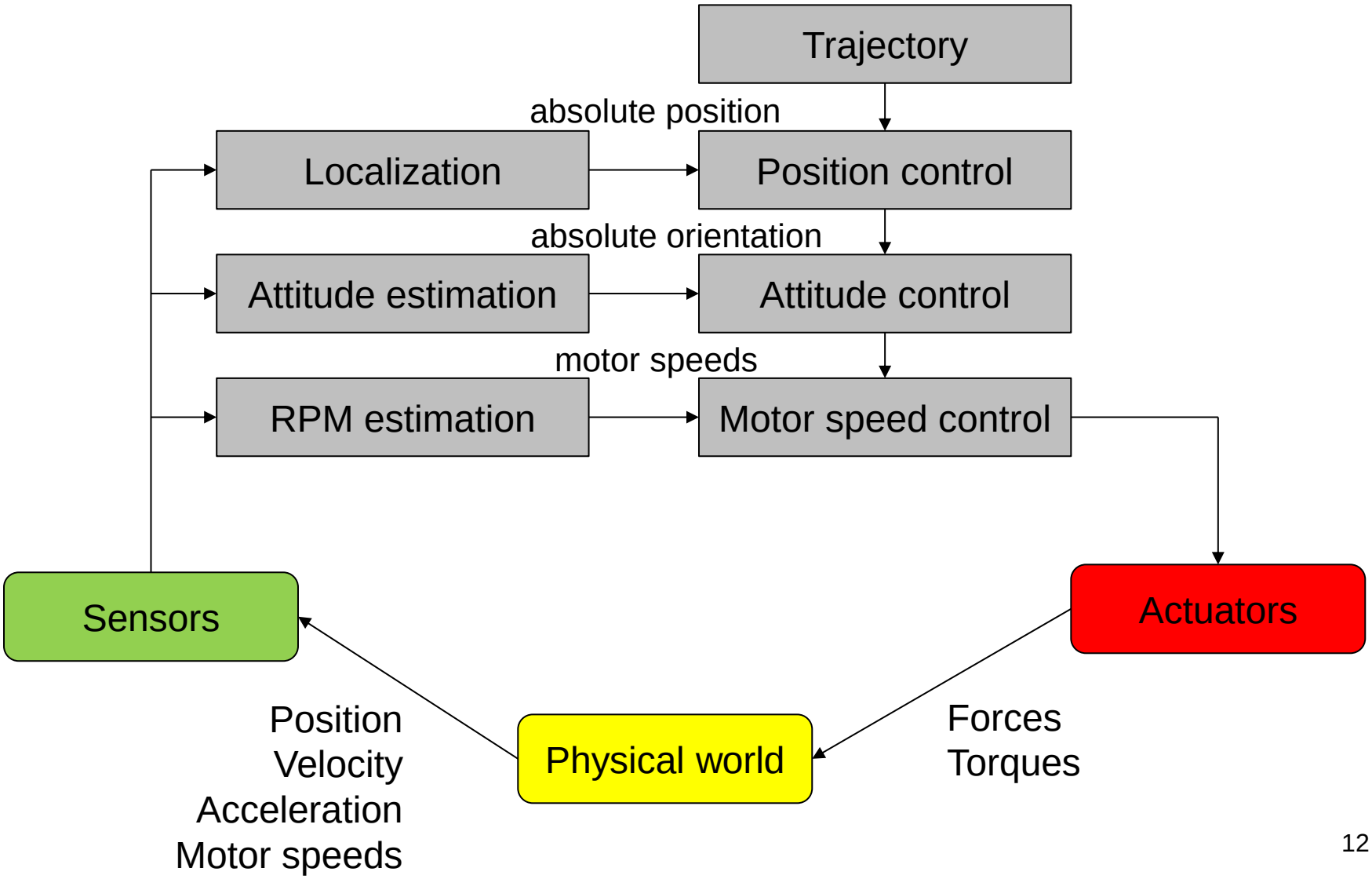


- Practically infeasible – control loop necessary
- Control loop means measuring deviation from hover position and then act against deviation
- What needs to be measured for this?
  - Is attitude/orientation enough? – If attitude is perfect zero than there is no movement

Elements of quadrotor control



Measurements needed for quadrotor control



Control timings

- Motor control happens on motor boards (controls every motor tick)
- Attitude control implemented on micro-controller with hard real-time (at 250Hz-1000Hz)
- Position control (at 4-250Hz)
- Trajectory (waypoint) control (at 0.1-1Hz)