

## ME 410 – Week 6

### Christopher Luey

#### (a) Text Description

##### Milestone 1 – Yaw P Control (*Completed Week 5*)

Disabled pitch and roll. Mapped left joystick to desired yaw rate; applied proportional control (Yaw\_gain = 2, Yaw\_amplitude = 50).

Logs confirmed alignment between commanded and measured yaw rates.

##### Milestone 2 – Attitude PID for Ground-Effect Hover

**Total Tuning Time:** 25 h (5 sessions), ~500 flights.

##### Thrust Stabilization

Thrust held at PWM = 1450 with magnitude of 200 to get off ground and reduce ground affect (~0.5 m hover in ground effect) to isolate attitude control.

##### Pitch Angle Debugging

Initial pitch estimates were inaccurate ( $\pm 5^\circ$ ). Diagnosed and resolved incorrect  $\text{atan2}()$  axis mapping — IMU X and Y accel inputs were swapped.

After correction, pitch error dropped to  $\pm 0.5^\circ$ , enabling clean loop behavior. Graphs were produced and verified by Professor Rubenstein in order to validate sensor data.

##### Tuning Protocol

- **D-Gain Sweep:** Start at  $D=0.00$ , increase by 0.5 to oscillation ( $D_0 \approx 0.70$ ). Binary search  $\rightarrow D^* = 3.5$  (Pitch and Roll).
- **P-Gain Sweep:** Fix  $D^*$ , increase P by 0.5 until oscillation ( $P_0 \approx 13.5$ ); binary search  $\rightarrow P^* = 5$  (Pitch and Roll).
- **D Rollback:** Step down in 0.02 increments until oscillations cease  $\rightarrow D = 3.43$  (Pitch),  $D = 3.24$  (Roll).
- **P-Gain Fine-Tune:** Increment P by 0.05 until drone responsive  $\rightarrow P = 5.2$  (Pitch),  $P = 4.85$  (Roll).
- **Yaw Tuning:** Increment Yaw Gain until spinning ceases  $\rightarrow Y\_gain = 0.8$

##### Roll Tuning Notes

Roll loop exhibited more sensitivity than pitch — higher oscillation frequency and greater response to

overdamping.

Required finer derivative tuning and lower P-gain to suppress instability.

### **Combined-Axis Validation**

10 s hover with both loops active: no cross-axis oscillation; logs showed  $<0.05$  m attitude-equivalent drift.

### **Final PID Gains**

- **Pitch:**  $P = 5.2$ ,  $D = 3.43$
- **Roll:**  $P = 4.85$ ,  $D = 3.24$

### **Milestone 3 – Free Ground-Effect Flight**

**Status:** Deadline Extended

### **(b) Task Assessment**

#### **Successes**

- Fixed IMU axis bug—enabled precise pitch estimation.
- Minimal yaw drift without I-control.
- Achieved stable hover with both pitch and roll loops active (PD controller).

#### **Challenges**

- *Pitch Estimate Bug:* Incorrect IMU axis mapping in `atan2()` fixed on Day 2 firmware patch.
- *Ground Effect:* Nonlinear thrust behavior  $<0.3$  m—resolved by holding  $PWM \geq 1450$  and magnitude = 200.
- *Roll Tuning:* Required careful damping to avoid overshoot and instability.
- *Yaw Drift:* Required slight P-gain increase to fully eliminate residual rate.
- *Inconsistent Behavior:* Drone would behave completely differently even with exact same tuning parameters based on initial conditions, solving PD gains for robustness was a challenge

- *Center of Mass*: Position of battery and wires affected performance significantly. Tape required to position battery precisely.

### **Planned Improvements**

- Dedicated session for Milestone 3 free-hover flight.
- Incorporating integral gain for flight to reduce drift

### **(c) Team Member Effort**

Both members were tuning together.

- **Jason (50%)**  
Performed ~25 hours of PD tuning
- **Christopher (50%)**  
Performed ~25 hours of PD tuning