Category: Low Prep
Domain: Aerial Robotics
Company Name: Drona Aviation
PS Name: Control system for Drone Stabilization and Precision Motion

Introduction

Indoor nano-drones operate with strict sensing and compute constraints. Without GPS or external tracking, stability depends entirely on how effectively the firmware interprets onboard sensors and closes the loop in real time. Even with reliable IMU data, a drone will drift or vary in altitude unless supported by a strong, fused control pipeline.

Modern systems achieve this by combining optical flow based motion, ToF altitude measurements, and IMU orientation into a consistent, low-latency estimate of the drone's state. This enables the aircraft to take off, lock its position, and maintain a steady hover autonomously.

In this challenge, the drone must hold its position and altitude by default, without any pilot input. Only when the user provides a command should it move, shifting precisely 10-20 cm in the indicated direction before stabilizing again at the new location. The focus is on delivering a robust, production-grade control system capable of clean sensor fusion, predictable behavior, and centimeter-level precision in real indoor conditions.

About Us

Drona Aviation Pvt. Ltd., led by IIT Bombay alumnus Mr. Dinesh Sain, is a leading force in bringing drone technology into India's education landscape. We bring cutting-edge aerial robotics into classrooms through programmable drones, modular learning kits, and hands-on technical workshops designed for practical, experiential STEM learning. As India's leading programmable drone platform with 50,000+ drones deployed globally, our Made-in-India Pluto 1.2 and Pluto X have become trusted tools for learning drone flying, coding, tinkering, prototyping, and real-world innovation. These classroom-safe, curriculum-ready platforms are designed to build future-ready technical skills. Our nationwide impact includes the Atal Drone Module officially adopted by 8,000+ Atal Tinkering Labs under NITI Aayog, bridging academic learning with real drone applications and empowering the young generation of innovators across India.

Problem Statement Description

Your Mission

Build a complete, on-board stabilization and precision-motion system that can:

- Take off on user command (single button trigger)
- Hold position and altitude without any further user input
- Maintain a stable hover with minimal drift
- Execute user-triggered micro-movements (10-20 cm) based on pitch, roll, or throttle input
- Stabilize immediately after each commanded displacement
- Maintain altitude up to 2 meters with consistent behavior
- Resist and recover from external disturbances
- Deliver predictable, smooth control responses
- Filter noise and handle poor sensor conditions gracefully
- Demonstrate stable, repeatable, production-grade performance across multiple flights
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Your implementation must run entirely within MagisV2 using only the provided APIs, sensors, and microcontroller compute.

What You Must Build

1. Real-Time Velocity Estimation:
    a. You must compute accurate horizontal velocities by:
        i. Converting optical-flow pixel shifts into real-world motion using real-time altitude data
        ii. Adjusting velocity estimates for yaw changes to maintain a stable world-frame reference
        iii. Handling low-texture or low-light situations using fallback logic and confidence checks
        iv. Maintaining high-frequency updates to support stable hover and precise micro-movements
    b. These velocity estimates directly drive:
        i. Position locking during hover
        ii. Controlled 10-20 cm user-triggered micro-displacements
        iii. Smooth deceleration and settling at the new position
        iv. Overall stability and drift minimization
2. Closed-Loop Control System
    a. The drone must be capable of:
        i. Automatically stabilizing and entering hover mode once airborne
        ii. Maintaining a fixed X-Y position and altitude without pilot stick input
        iii. Executing precise 10-20 cm movements when the user applies pitch, roll, or throttle commands
        iv. Stabilizing immediately at the new position after each micro-movement
        v. Recovering cleanly from external disturbances (pushes or pulls)
        vi. Minimizing drift during prolonged hover
        vii. Responding to user inputs smoothly, without overshoot or oscillation

   b. A cascaded control architecture (Position → Velocity → Attitude) is expected, though teams may innovate beyond PID if properly justified.
   c. The controller must ensure:
      i. Predictable transitions between hover and movement
      ii. Stable behavior across different textures, lighting, and altitudes
      iii. Clean re-entry into hover mode after each commanded displacement
      iv. Deterministic, low-noise control actions suitable for production firmware

3. Sensor Fusion Under Real Conditions
   a. You must combine Optical Flow, ToF, IMU and Baro data using reliable and explainable logic such as:
      i. Complementary filtering
      ii. Kalman-style filters
      iii. Adaptive gain fusion
      iv. Any alternative approach that maintains deterministic behavior
   b. The fusion system must remain stable and deliver clean state estimates during:
      i. Low-texture or uneven surfaces
      ii. Rapid or uneven lighting changes
      iii. Optical flow dropouts, spikes, or low-confidence readings
      iv. ToF noise at higher altitudes
      v. Slow yaw rotations during hover or micro-movements
      vi. Micro-vibrations caused by motors or sudden directional shifts
   c. The fused state must support:
      i. Accurate hover without user input
      ii. Precise 10-20 cm user-triggered displacement commands
      iii. Fast recovery back into stable hover after motion
      iv. Smooth transitions even when sensor quality temporarily degrades
   d. Failure cases must degrade gracefully and should not cause divergence, oscillations, or unexpected drift.
4. Altitude Stability up to 2 Meters
   a. Your altitude controller must demonstrate:
      i. Stable hover Minimum 0.5 Meters for minimum one minute
      ii. Low oscillations
      iii. Noise filtering
      iv. Consistent behavior across heights
   b. A special evaluation includes a high-altitude consistency test up where stability, drift, and control authority are examined.
   c. No surface, lighting, or texture biases are allowed.

5. Precision Motion (User-Triggered Micro-Movement Mode)
   a. Autonomous Hover by Default
      After takeoff, the drone must independently stabilize and hold its position and altitude

without any user input.

b. Hands-Free Position Lock
The system must maintain a drift-free hover until a user explicitly generates a control input.

c. Input as a Displacement Command, Not Velocity
Any stick movement (pitch/roll/throttle) must translate into a discrete 10-20 cm movement, not continuous motion tied to stick holding.

d. Directional Micro-Movement
Example behaviors:
   - Pitch forward → move forward 10-20 cm
   - Roll left → move left 10-20 cm
   - Throttle up → climb 10-20 cm

e. Adaptive Mapping
Stick deflection may scale the displacement within the 10-20 cm range while retaining full control stability.

f. Smooth Motion Profile
Each micro-movement must include controlled acceleration and deceleration with minimal jerk.

g. No Overshoot
The drone must stop precisely at the commanded displacement with ±2 cm tolerance.

h. Instant Hover at New Position
After reaching the target point, the drone must automatically return to hover mode and lock the new X-Y-Z position.

i. Robust Against Tiny Inputs
Small, accidental bumps or noise on the sticks must be rejected; only intentional inputs should trigger motion.

6. Your design should reflect:
   a. Deterministic and predictable behavior in both hover and micro-movement modes
   b. Clean transitions between user-triggered 10-20 cm movements and stable hover
   c. Low oscillations, minimal drift, and smooth control authority
   d. Modular, maintainable architecture suitable for real firmware integration
   e. Clearly tuned control and fusion parameters with documented reasoning
   f. Reliable performance across repeated flights, different indoor environments, and varied textures
   g. Stable behavior even under partial sensor degradation or brief dropouts
   h. Consistency across the entire altitude range up to 2 meters
   i. Robust fail-safe handling without unexpected drift or runaway motion
   j. Firmware quality that meets the standards required for production release within MagisV2

Deliverables

1. **Firmware Implementation**
   A complete, modular codebase running inside MagisV2 that includes:
   a. Sensor reading and filtering for Optical Flow, ToF, and IMU
   b. Real-time velocity and position estimation for stable hover
   c. Position-velocity-attitude control loops
   d. Auto-hover after takeoff
   e. User-triggered micro-movement handling
   f. Smooth motion execution and stable settling
   g. Tuneable control and fusion parameters
   h. Robust fallback behavior under poor sensor conditions

2. **Documentation**
   A clear technical document covering:
   a. System architecture overview
   b. Control design and reasoning for hover and micro-movements
   c. Sensor fusion strategy for OF, ToF, and IMU
   d. PID tuning approach and key parameters
   e. Hover and micro-movement performance results
   f. Limitations, failure cases, and lessons learned

3. **Demonstration Video**
   Showcase:

   a. Takeoff using the designated button
   b. Stable hover with no user stick input
   c. Horizontal drift within acceptable limits
   d. Altitude stability Up-to 2 meter
   e. Recovery from small external disturbances
   f. User-triggered 10-20 cm movements in all directions
   g. Immediate stabilization at each new position and altitude

   Dashboard overlays (velocity, ToF, OF) are encouraged.

Evaluation Criteria

1. **Stability & Precision (40%)**
   a. Hover stability without user input
   b. Minimal drift during extended hover
   c. Smooth execution of 10-20 cm user-triggered movements
   d. Accurate settling at the new position and altitude
   e. Low oscillations and predictable corrections

2. **Control System Design (25%)**
    a. Correct implementation of a cascaded Position-Velocity-Attitude architecture
    b. Clean transition between hover mode and micro-movement execution
    c. Well-tuned control gains with stable, non-oscillatory response
    d. Predictable behavior during acceleration, deceleration, and settling
    e. Clear justification of control strategies and parameter choices

3. **Sensor Fusion Quality (20%)**
    a. Clean and reliable fusion of Optical Flow, ToF, and IMU data
    b. Stable estimates during hover and micro-movement execution
    c. Robust handling of dropouts, spikes, and low-confidence readings
    d. Smooth behavior across varying textures, lighting, and altitudes
    e. Consistent state estimation supporting precise 10-20 cm movements

4. **Engineering Innovation (10%)**
    a. Advanced filtering or sensor fusion approaches
    b. Efficient or optimized control strategies
    c. Useful visualization or debugging tools
    d. Adaptive or predictive features that enhance stability
    e. Creative but practical solutions that improve reliability

5. **Documentation & Presentation (5%)**
    a. Clear and well-structured technical documentation
    b. Easy-to-understand explanation of design decisions
    c. Concise presentation of results and performance
    d. Effective use of visuals, graphs, or overlays
    e. Overall clarity and completeness of the submission