National University of Sciences and Technology (NUST)
School of Electrical Engineering and Computer Science

Department of Electrical Engineering

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Semester: Sixth **Section:** A

EE-371: Linear Control Systems

Project Proposal

Name	Reg. No	PLO4/ CLO5 Viva / Quiz / Lab Performance 5 Marks	PLO4/ CLO5 Analysis of data in Lab Report 5 Marks	PLO5/ CLO6 Modern Tool Usage 5 Marks	PLO8/ CLO7 Ethics and Safety 5 Marks	PLO9/ CLO8 Individual and Team Work 5 Marks
Muhammad Ashar Javid	404818					
Muhammad Hammad Sarwar	408991					
Awais Asghar	427265					
Ameer Hamza	412230					

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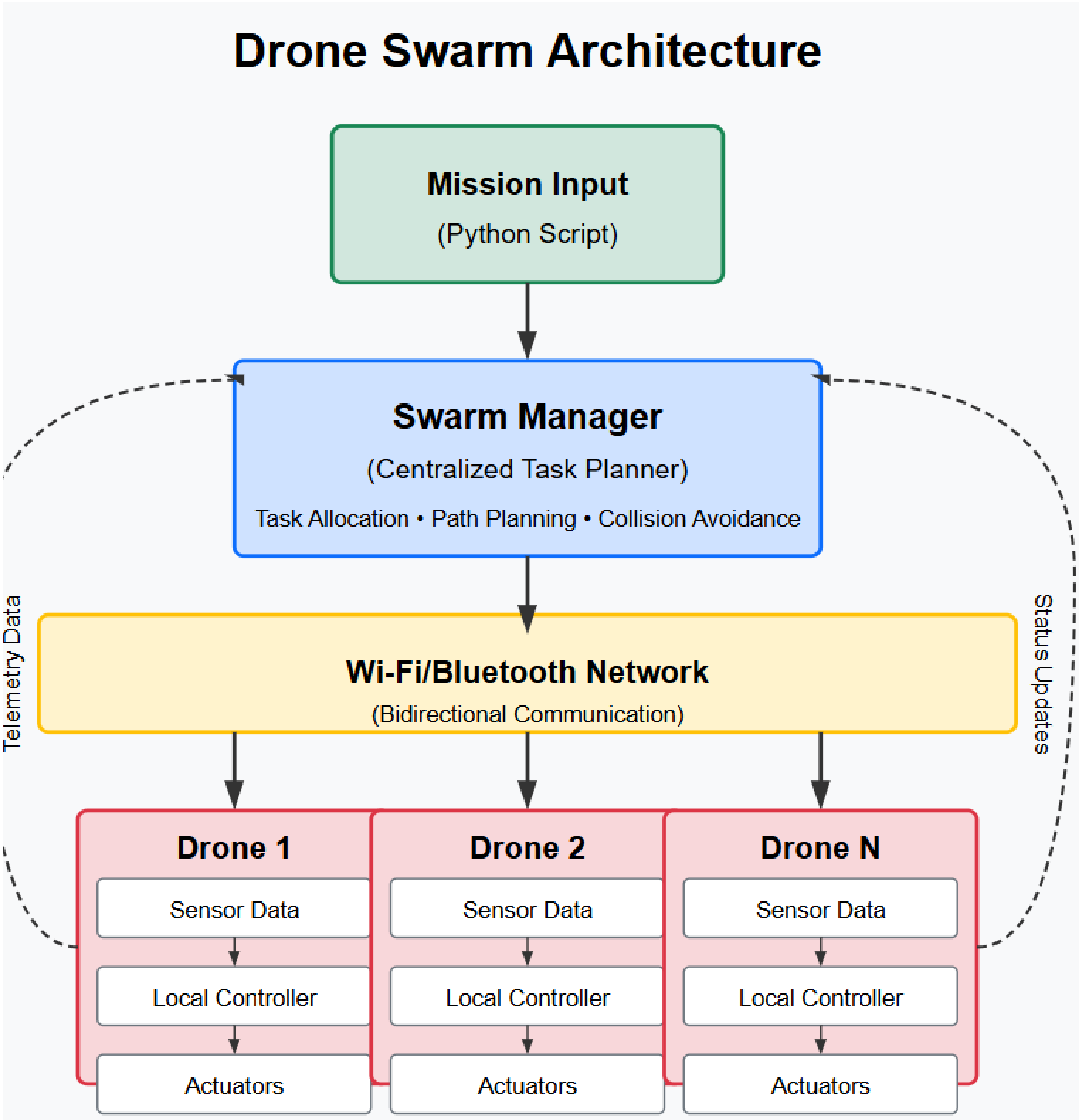
Aims and Objectives:

To design a simplified yet robust linear control system for coordinating a drone swarm capable of executing complex tasks (e.g., dynamic formations) using off-the-shelf hardware and decentralized algorithms.

1. **Swarm Control Basics:**
   - *Stabilize individual drones using PID controllers for altitude, and position.*
   - *Implement algorithms for decentralized swarm coordination (velocity alignment, formation keeping).*
2. **Task Execution:**
   - *Demonstrate dynamic formation changes (e.g., line → circle → diamond).*
   - *Enable collision-free navigation in obstacle-dense environments using repulsion-based control.*
3. **Intercommunication:**
   - *Use Wi-Fi/Bluetooth for peer-to-peer communication (using ESP32).*
   - *Implement lightweight messaging for position/velocity sharing (e.g., UDP packets).*
4. **Validation:**
   - *Testing in simulation (Gazebo) and with a hardware 3-drone setup.*

Block Diagram:



Key Components:

1. **Drones:**
   - Use pre-built drones (e.g., Crazyflie 2.1) with built-in STM32 controllers and radios.
   - Sensors: IMU (gyro/accelerometer), optical flow for indoor positioning.
2. **Communication:**
   - Wi-Fi Broadcast: Each drone broadcasts its state (x, y, z, velocity) over UDP.

o Python-based Swarm Manager: Runs on a laptop to assign tasks and monitor swarm status.

3. **Control Algorithms:**

o PID for Individual Stability:

- Altitude control via throttle adjustment.
- Attitude control (pitch/roll) using gyro feedback.

o Swarm-Level Coordination:

- Velocity Consensus: Adjust drone velocity to match neighbors' average.
- Formation Control: Offset tracking

Real-World Setup

1. **Hardware:**

Drones: 3.

Communication: Built-in Crazyradio PA (2.4 GHz) for low-latency control.

Positioning:

Outdoor: GPS module.

2. **Software:**

- Firmware: Extend Crazyflie's PID controller for swarm logic.
- Swarm Manager: Python script using cflib library to send setpoints.

Expected Results:

1. **Basic Swarming:**
   a. Drones maintain formation with ±0.3m accuracy in moderate turbulence.
   b. Seamless velocity alignment within 2 seconds of disturbance.
2. **Complex Tasks:**
   a. Transition between 3 formations in <30 seconds.
   b. Navigate obstacle courses with a good success rate.
3. **Scalability:**
   a. A system architecture design that supports up to 3 drones with <100ms communication latency.

Conclusion:

This project simplifies drone swarm control while retaining the ability to execute complex tasks. By leveraging affordable, off-the-shelf drones and lightweight algorithms, it demonstrates core principles of linear control systems in multi-agent coordination. The results will provide a foundation for future work on adaptive control or machine learning-enhanced swarming.

References:

1. Crazyflie Official Documentation: https://www.bitcraze.io/documentation/
2. Murray, R. M. (2017). A Mathematical Introduction to Robotic Manipulation. CRC Press.
3. ROS Swarm Robotics Packages: https://github.com/ros-swarm
4. Olfati-Saber, R. (2006). “Flocking for Multi-Agent Dynamic Systems: Algorithms and Theory.” IEEE Transactions on Automatic Control.