DESIGN AND FABRICATION OF AUTONOMOUS DRONES FOR GPS DENIED AREA

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Introduction:
Autonomous drones designed for GPS-denied environments enable operation where traditional navigation fails, such as indoors, dense cities, forests, or underground spaces. They use technologies like SLAM and visual odometry to estimate position and map surroundings in real time. Sensors including LiDAR, depth cameras, ultrasonic sensors, and IMUs provide accurate perception. Sensor fusion combines this data to improve reliability and accuracy. Onboard processors handle real-time processing and AI-based decision-making without external networks. These drones operate using a perception–decision–action loop to adapt continuously. Advanced obstacle detection ensures safe navigation in complex environments. They are widely used in search and rescue, inspections, warehouses, and military missions. Challenges include achieving GPS-level accuracy, computational limits, and battery constraints. Despite this, advancements in AI and sensors are making these drones more robust and efficient.

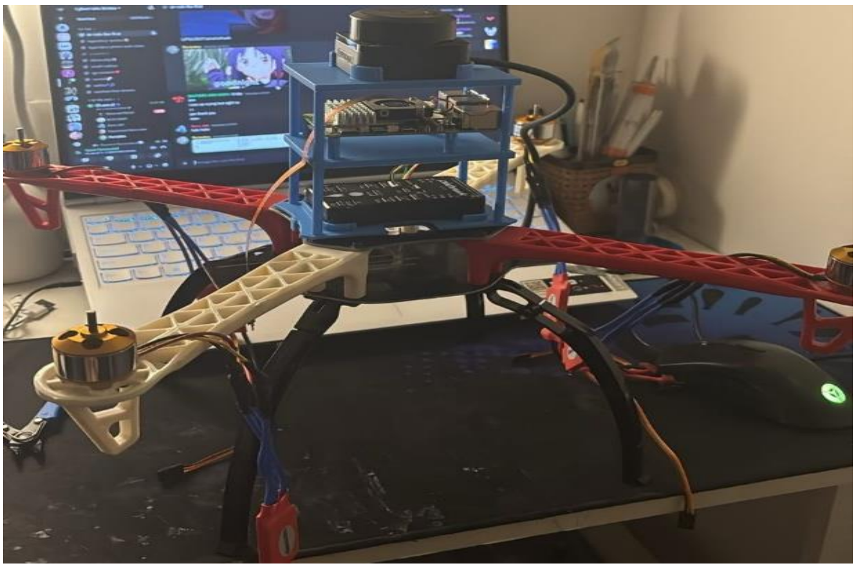

Figure 1: Test fitting drone with the autonomous system

Objectives:

1. To design and develop an autonomous UAV system capable of operating reliably in GPS-denied environments by overcoming challenges related to localization, sensor uncertainty, and constrained navigation spaces.
2. To implement vision-based and ranging sensor-based techniques for accurate localization and safe navigation without reliance on GPS, ensuring real-time obstacle avoidance and mission execution. List the objectives 3 of project

Methodology:

- Assemble the quadcopter frame (F450) with landing gear and structurally integrate all components, ensuring proper weight distribution, vibration isolation for sensors, and secure mounting of avionics.
- Install A2212 1000KV BLDC motors with 1045 propellers and interface them with SimonK 30A ESCs, followed by precise calibration of ESC throttle range to achieve synchronized motor response.
- Design and implement a robust power distribution system using the Matek PDB-XT60, integrating the 3S LiPo battery and ensuring regulated voltage supply to the flight controller, onboard computer, and peripheral modules via DC-DC converters.
- Mount and configure the Pixhawk 2.4.8 flight controller, establishing connections with ESCs, IMU, and telemetry interfaces, and perform initial firmware flashing and sensor calibration for stable flight control.
- Integrate the Raspberry Pi 5 as the onboard companion computer, providing adequate cooling and stable power, and establish MAVLink-based communication with the Pixhawk for high-level control and data exchange.
- Install and calibrate the MicoAir MTF-01 optical flow and range sensor to enable accurate relative positioning and altitude estimation in GPS-denied environments.
- Deploy the SLAMTEC RPLiDAR C1M1-R2 and Raspberry Pi Camera Module 3 to enable multi-sensor perception, facilitating real-time environment mapping, obstacle detection, and visual odometry.
- Develop and implement sensor fusion algorithms within a ROS 2 framework, combining LiDAR, camera, and optical flow data to achieve reliable localization and mapping using SLAM techniques.
- Design and integrate real-time obstacle avoidance and path planning algorithms, enabling autonomous navigation in dynamic and constrained environments without reliance on GPS signals.
- Conduct systematic testing and validation in controlled indoor environments, followed by iterative tuning of PID parameters, SLAM accuracy, and navigation algorithms to achieve stable, precise, and fully autonomous flight performance.

Result and Conclusion:

In conclusion, Autonomous drone operation in GPS-denied environments is a key advancement driven by the limitations of satellite-based navigation in complex areas like indoors, forests, and urban regions. Advanced techniques such as SLAM, visual–inertial odometry, sensor fusion, and AI-based navigation are essential for achieving reliable autonomy without GPS. Integration of AI methods like computer vision and reinforcement learning improves adaptability and decision-making in dynamic environments. Decentralized and swarm-based systems enhance robustness, enabling cooperative localization and reliable mission execution. However, challenges such as sensor drift, power constraints, environmental limitations, and ethical concerns still affect real-world deployment.

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Future Scope:

The future scope of this project includes:

1. **Advanced Multi-Sensor Fusion for Robust Localization:** Integrates visual–inertial SLAM, event-based cameras, depth sensing, and radar to achieve accurate and drift-free navigation in complex GPS-denied environments.
2. **Adaptive AI-Based Navigation and Decision Making**: Utilizes learning-based models with self-diagnosis to enable intelligent navigation, obstacle avoidance, and recovery from localization failures.
3. **Edge AI Optimization and Cooperative Swarm Intelligence**: Employs efficient onboard AI processing and inter-drone communication to ensure real-time performance and enhanced resilience through collaborative navigation.