AUTONOMOUS FIXED WING UAV SYSTEM FOR AUTOMATIC PAYLOAD DELIVERY AND LINEAR SURVEILLANCE

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Introduction:

Autonomous fixed-wing UAVs are rapidly emerging as a transformative technology for long-range delivery of delicate payloads, addressing critical needs in diverse sectors like healthcare, environmental monitoring, and disaster relief. Their inherent advantages in range and endurance, compared to multirotor platforms, make them ideal for reaching remote or inaccessible areas. However, the successful deployment of these systems hinges on the precise and reliable delivery of fragile payloads, demanding sophisticated integration of navigation, control, and release mechanisms.

The core challenge lies in maintaining accuracy and stability during flight, especially in dynamic environmental conditions, and executing a controlled release to minimize impact on the payload. This requires meticulous design of the airframe, selection of appropriate sensors, and development of robust control algorithms that can compensate for wind gusts, turbulence, and other disturbances. As advancements in materials, propulsion systems, and artificial intelligence continue to progress, autonomous fixed-wing UAVs are poised to revolutionize delivery logistics, offering efficient and reliable solutions for a wide range of applications.

Objectives:

- Develop an autonomous fixed-wing UAV system for precise payload delivery
- Implement advanced surveillance with integrated data post-processing for seamless UAV operation and monitoring

Methodology:

The fixed-wing UAV is designed and fabricated to gain aerodynamic stability and efficiency while flying. Its streamlined airframe provides the UAV with long-distance travel with minimal air drag, hence assisting the UAV in reducing drag and fuel consumption. An optimized airframe allows the UAV to conduct missions, such as accurate payload delivery, where it is designed for the delivery of supplies, packages, or equipment at a precise location as commanded.

The UAV structure is optimized so that it weighs as lightly as possible and holds up at the same time. Lightweight materials are used, thereby reducing the total mass of the structure, which is to say that the fuel efficiency of the UAV (or power efficiency in the case of electric UAVs), can stay airborne longer. The important applications for extended flight times include surveillance or search and rescue, and delivery missions in remote locations.

The materials for the aircraft were selected based on the principles of minimizing weight while maximizing strength, as lightweight design is a fundamental aspect of flight. The primary material used for fabrication was foam sheets, chosen for their extremely light weight, structural strength, and ease of molding. Foam was predominantly used in the construction of the fixed wing. Additionally, a small amount of balsa wood was incorporated due to its favourable properties, including light weight, good strength, and elasticity, though its use was limited to specific areas.

Aligned with the AI onboard, real-time data analyses are applied in flight, with algorithms continually working through information generated by onboard sensors—like cameras, GPS, and environmental sensors—to detect key events such as obstacles, terrain changes, or targets.

To enable these autonomous operations, the UAV integrates essential electronic components such as a Pixhawk flight controller, NEO GPS module, and telemetry system, along with onboard sensors and a servo-controlled payload release mechanism. These components collectively facilitate stable flight, accurate navigation, and mission execution.

A real-time communication system ensures that the UAV and the ground control station link their data continuously. Data is transferred between the UAV and the ground control station uninterruptedly, offering endless possibilities for operators of the control station on the ground to monitor the progress of the UAV, obtain critical updates, and possibly even control some operations of the UAV if need be. With such a system, critical information picked out would mean that important data anomalies detected during surveillance or even alerts about the malfunction of the system can be reported to the ground control right away. It would allow real-time decision-making and modifications, if any, to the mission.

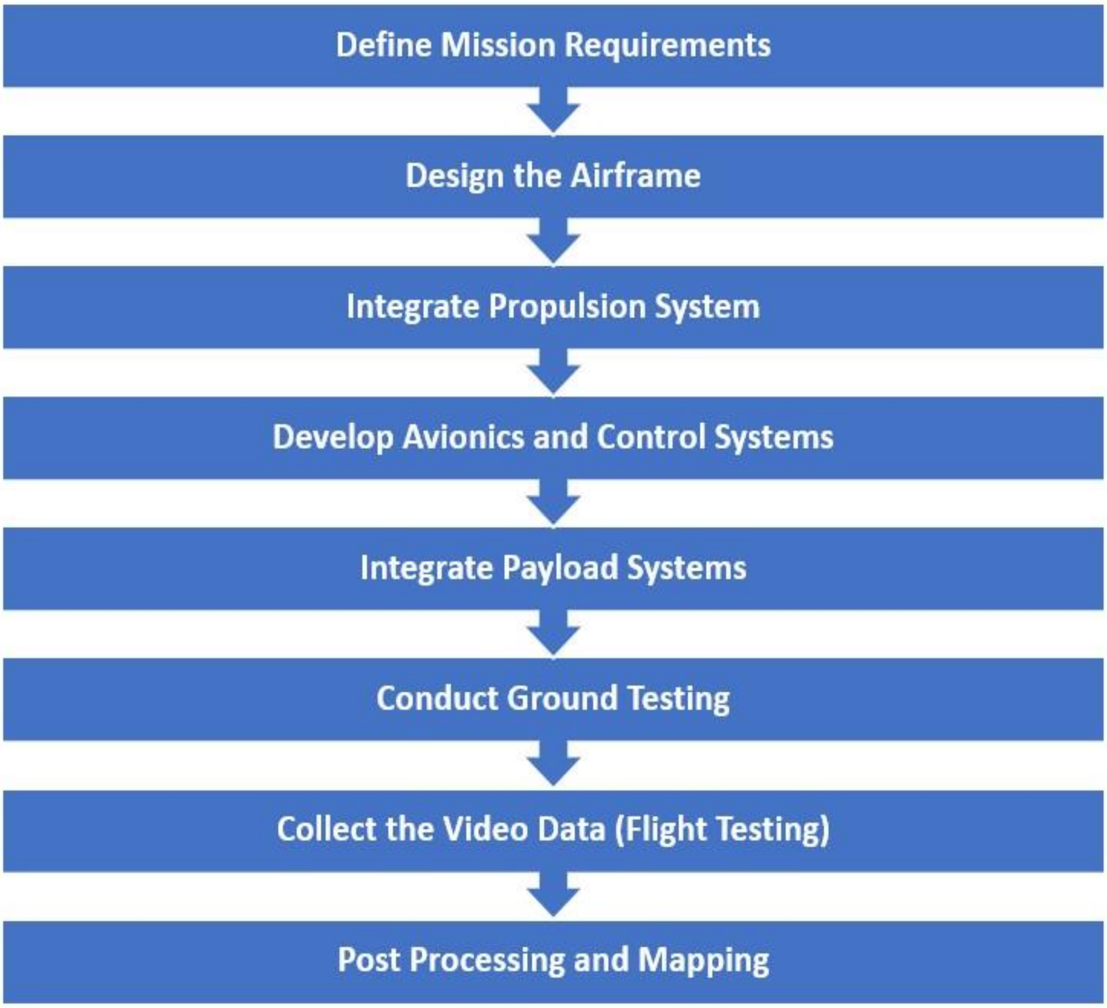

Figure 1: Flowchart representing the steps followed

Results and Conclusions:

The fixed-wing aircraft has been thoughtfully designed and meticulously crafted to meet demanding specifications, making it a versatile platform for general logistics. With the capability to carry a minimum payload of 1.2 kg and an endurance of over 21 minutes, this aircraft is well-suited for delivering essential goods to remote or hard-toreach areas. Whether it's transporting supplies to rural communities or supporting lastmile deliveries in rugged terrains, its lightweight design ensures both efficiency and reliability.

In addition to its logistics capabilities, the aircraft is equipped with an onboard camera for surveillance. This feature makes it ideal not only for transporting goods but also for conducting aerial inspections, monitoring large areas, or supporting search-and-rescue operations.

Combining its payload delivery functionality with surveillance capabilities, this aircraft represents a significant advancement in logistics and aerial monitoring, seamlessly blending innovation with practicality for a wide range of applications.

Testing confirmed the UAV’s autonomous flight capabilities, accurate payload deployment, and stable flight path following, including coordinated yaw, pitch, and roll adjustments. Post-processing on flight video successfully produced panoramic stitched images using frame extraction, feature matching, and homography techniques.

This validates the aircraft’s design and software pipeline as both functionally robust and field-ready.

Fig 2: Autonomous Flight Test at B.C. Alva Stadium

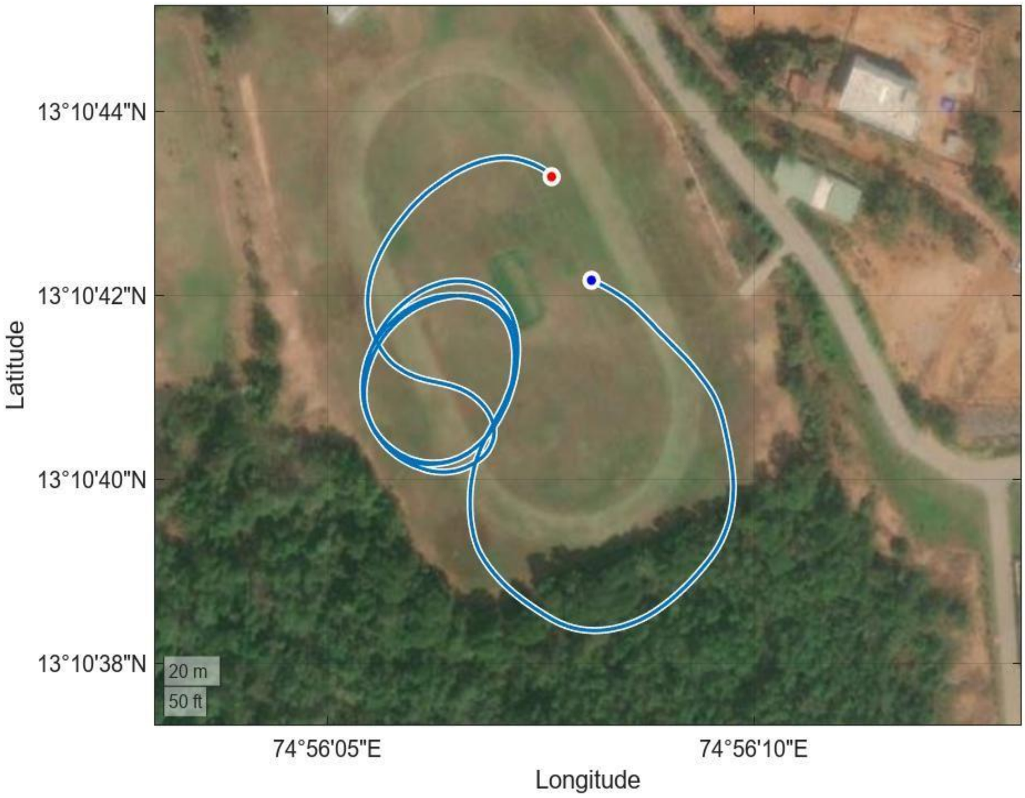

Fig 3: Simulated Flight Path

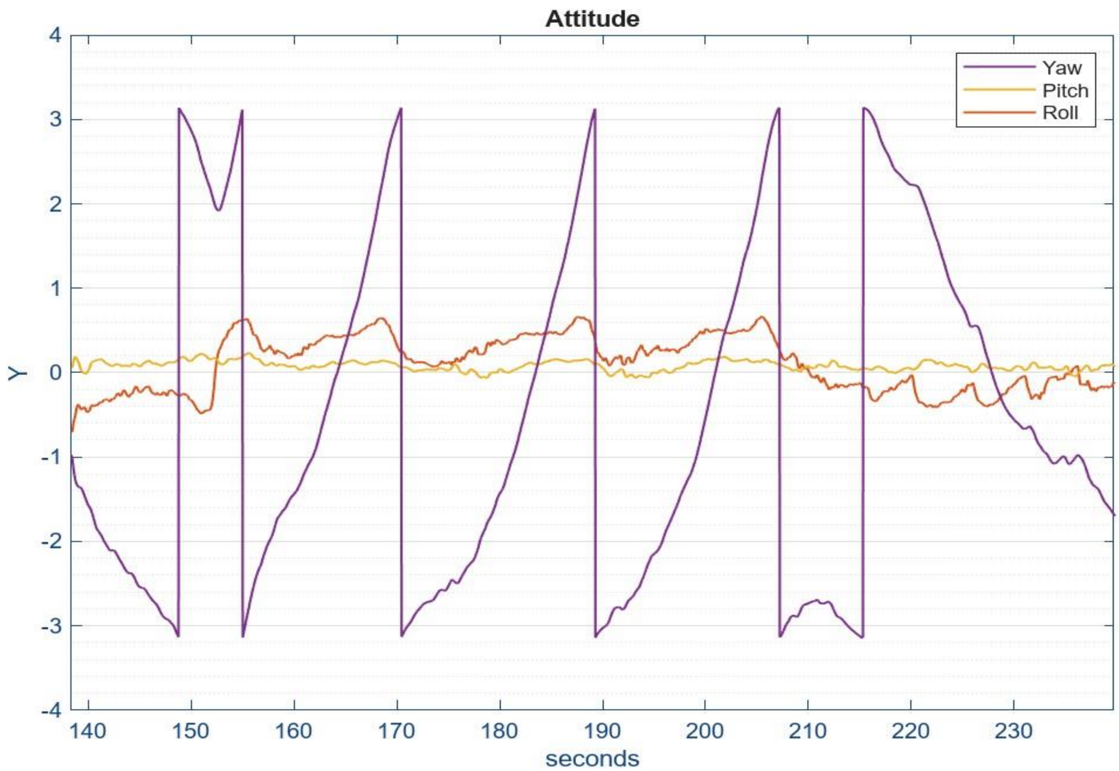

Fig 4: UAV Attitude Graph – Yaw, Pitch, and Roll

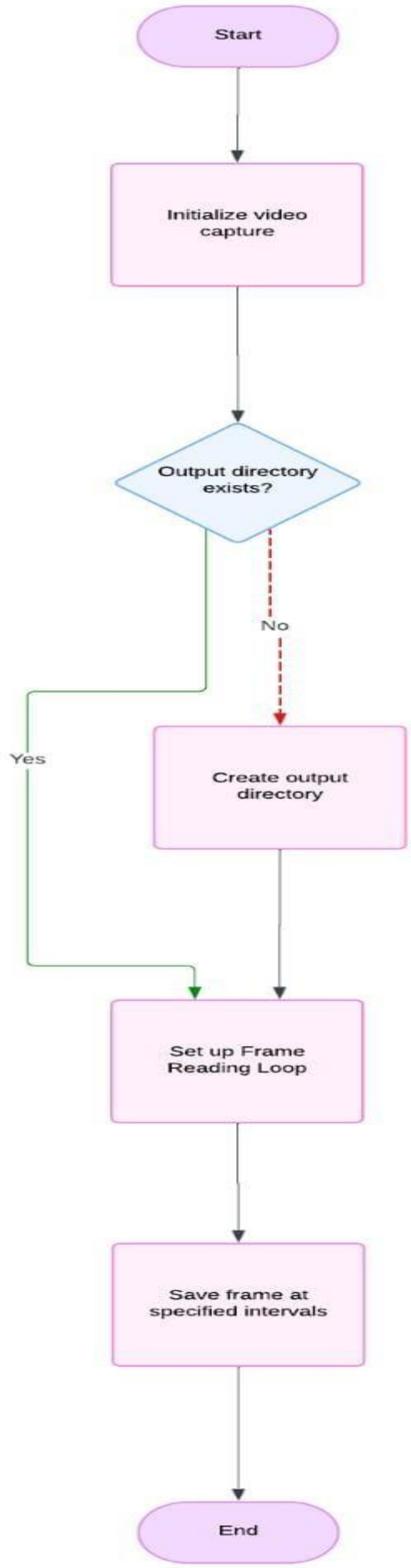

Fig 5: Video Frame Extraction for Post-Processing

Fig 6: Final Panoramic Stitched Image Output

Project Outcome & Industry Relevance

The developed autonomous fixed-wing UAV system has proven capable of performing precise payload deliveries and advanced linear surveillance over long distances. Its ability to carry up to 1.2 kg payload and sustain 21+ minutes of flight offers a practical solution for last-mile logistics, particularly in remote or disaster-affected areas.

Real-time data processing and autonomous navigation make it ideal for applications like border patrol, pipeline inspection, agricultural monitoring, and search-and-rescue missions. The integration of AI algorithms and onboard sensing systems enhances its adaptability in diverse operational conditions.

This system offers a cost-effective, scalable alternative to traditional delivery and surveillance methods, minimizing human intervention and increasing efficiency. Its modular design and lightweight structure further contribute to ease of deployment and customization for varied industry needs.

Working Model:

This project involved the development of a physical working model of an autonomous fixed-wing UAV. The UAV was designed, fabricated, and tested under real-world conditions, successfully demonstrating autonomous flight, payload deployment, and onboard data processing.

The flight test confirmed the UAV's ability to follow a pre-planned path autonomously, and maintain flight stability throughout the mission. Supporting evidence such as the flight test (Fig. 2), simulated flight path (Fig. 3), and UAV attitude graph (Fig. 4) validate its functionality and mission execution in live conditions.

All core systems—structural airframe, electronics, flight controller, sensors, AI algorithms, and payload mechanism—were integrated into a single unit and tested in the field. The outcomes verify that the project is a fully functional hardware-based working model, and not a simulation or theoretical study.

Project Outcomes and Learnings:

The project resulted in the successful development of a fully functional autonomous fixed-wing UAV capable of performing accurate payload delivery and linear surveillance. The UAV achieved stable flight, autonomous waypoint navigation, payload release, and post-flight data processing for aerial image stitching using onboard camera data.

Key outcomes include:

- Autonomous flight with real-time GPS-based navigation.
- Onboard AI-assisted data collection and terrain analysis.
- Accurate payload deployment at targeted locations.
- Creation of stitched panoramic views from flight footage for surveillance and monitoring purposes.

Throughout the project, the team gained valuable insights into aerodynamics, flight control systems, and embedded system integration. Hands-on experience with UAV fabrication, mission planning, and software-hardware synchronization deepened our understanding of practical UAV applications. We also learned how to troubleshoot realtime issues, analyse flight logs, and improve mission accuracy through iterative testing.

The interdisciplinary nature of the project strengthened our skills in electronics, programming, teamwork, and project management essential for solving real-world engineering challenges.

Future Scope:

1. The future of fixed-wing UAVs is geared towards significantly extending their operational reach and autonomy. Advancements in battery technology and lightweight materials will enable longer flight durations, expanding their utility in remote logistics and surveillance.
2. The integration of sophisticated AI-driven navigation and obstacle avoidance systems will enhance their ability to operate safely and reliably in complex environments, paving the way for fully autonomous missions.
3. Coordinated UAV fleets will revolutionize large-scale logistics, requiring robust communication networks and seamless data transfer, particularly in areas with limited connectivity.
4. Modular payload architectures will allow for greater versatility, enabling UAVs to adapt to diverse mission requirements, from medical deliveries to environmental monitoring.
5. Developments in weather-resistant designs and durable airframes will ensure consistent performance in adverse conditions, extending their operational lifespan.
6. The integration of VTOL capabilities, noise reduction technologies, and optimized aerodynamics will further enhance their applicability in urban environments.
7. Robust regulatory frameworks, cybersecurity measures, and advanced sensor integration will be crucial for safe and efficient operation.
8. Dedicated UAV traffic management systems, alongside standardized communication protocols, will ensure seamless integration into future airspace.