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From Control Loss to Autonomous Operation: Failsafe Strategies for Modern UAVs

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***Annotation* — This paper analyzes the operating principles of the ExpressLRS radio control system for unmanned aerial vehicles (UAVs). It examines mechanisms for protecting UAVs from loss in the event of signal loss and explores various UAV behavior options in such situations. The study identifies possible ways to implement UAV protection mechanisms and highlights the potential for the UAV to perform a specific task even after radio communication with the operator is lost.**

***Keywords* — UAV, ELRS, Failsafe, re-navigation**

I. Introduction

In an era of rapid technological advancement and a growing need for process automation, unmanned aerial vehicles (UAVs) are gaining increasing importance. They are widely used across many fields, such as monitoring, mapping, cargo delivery, agriculture, logistics, infrastructure projects, scientific research, rescue operations, and the military. UAVs contribute to improved task efficiency, reduced human risk, and lower operational costs.

Developing effective control systems and behavior models for UAVs is essential for their reliable and safe operation. Today's economic conditions drive businesses and organizations to implement cutting-edge technologies that enhance process optimization and increase competitiveness. In this context, creating high-quality UAV control systems is especially relevant [1].

In addition to civilian applications, UAVs play a significant role in the military domain. They are used for reconnaissance, surveillance, target acquisition, and even direct target engagement. Developing reliable UAV control systems is crucial to ensure their effective operation in combat conditions. Modern conflicts illustrate that UAVs are becoming an integral part of military operations, enhancing the precision and effectiveness of armed forces.

The objective of this study is to analyze the operating principles of the ExpressLRS radio control system for unmanned aerial vehicles (UAVs) and investigate the available mechanisms for protecting UAVs from loss in cases of signal failure. This involves exploring various UAV behavior models under signal loss scenarios, evaluating their feasibility, and proposing optimal strategies for effective UAV control in emergency situations.

II. Problem Statement

ExpressLRS is an open-source radio control system designed to provide high data transmission speeds and long-range control for multirotors and other unmanned aerial vehicles (UAVs). It allows users to customize communication parameters for optimal performance in high-speed conditions and during long-distance flights, which is crucial for drone racing and first-person view (FPV) flights [2].

The ExpressLRS system is characterized by its high signal update rates and low latency, enabling operators to achieve maximum responsiveness and stable control of the aircraft. Its configuration offers flexibility and precision, which are essential for enhancing flight efficiency and meeting various operational tasks.

However, one of the pressing challenges that needs to be addressed today is ensuring the UAV's functionality in the event of a loss of control signal from the operator.

III. Solutions to the Problem Statement

The ability of an aircraft to operate autonomously in the event of a loss of radio communication signal is a pressing issue for the functionality of many aerial vehicles today. The development of systems that create interference in the radio spectrum necessitates finding ways to combat these disruptions. There are several approaches to addressing this problem.

One option is to transition from radio control to wired optical fiber control systems. This provides nearly absolute protection from interference; however, it limits the UAV's range and maneuverability capabilities.

Another option involves developing mechanisms that use signal receivers operating on different frequencies with a difference of several hundred megahertz. This method can partially mitigate the loss of control, provided that the created interferences do not cover all frequency ranges.

A further solution is the development of systems capable of autonomously maintaining UAV flight based solely on the information they can gather during operation. Typically, this information includes data from the flight controller's gyroscope and the ability to receive video (either analog or digital) from the UAV's camera. By equipping such a system with high-quality imagery, sufficient computational power, and an analysis system based on artificial intelligence, it can address both the problem of UAV functionality during a loss of control signal and the ability to perform specific tasks assigned to the aircraft..

Failsafe is a protection mechanism in radio control systems for unmanned aerial vehicles (UAVs) that activates when the drone loses signal from the remote control. If the drone ceases to receive commands from the operator due to reasons such as interference or exceeding the transmitter's range, the failsafe system automatically engages to minimize the risk of crashes or loss of the drone.

The configuration parameters for failsafe mechanisms can vary widely. For instance, in the Betaflight software environment, designed for flight controller firmware, the following primary actions can be configured:

Motor Shutdown: Upon losing communication, the drone immediately shuts down its motors to prevent uncontrolled flight.

Hovering or Position Hold: Some drones will maintain their current position while waiting for signal recovery.

Return to Home (RTH): The drone can return to its launch point (if equipped with GPS), which is particularly useful for long-distance flights.

Soft Landing: If the drone is in a safe area, the failsafe can initiate a gradual descent and landing.

However, none of these methods for handling signal loss and subsequent re-navigation will be effective if the computational capabilities of the flight controller are limited by a weak processor and insufficient onboard memory.

These limitations necessitate the installation of a separate computing unit onboard the UAV for automatic battlefield reconnaissance. Therefore, selecting an Orange Pi board is advisable due to its high capabilities and extensive functionality.

The connection of this system is sequential, meaning that the UAV's operation in normal mode should be managed by a pilot advancing toward enemy positions. Battlefield analysis begins as soon as the flight starts. If communication between the control module and the drone is lost for various reasons (interference or electronic warfare), the Orange Pi takes over control of the UAV without delay. At this moment, the drone's flight controller switches to ANGLE mode, which provides stabilization relative to the horizon. The Orange Pi computer reads data from the barometer and attempts to find the optimal throttle position.

Subsequently, a re-navigation system will operate, sending signals for THROTTLE, PITCH, and YAW to effectively hit the target, similar to the ELRS receiver's functionality.

Target recognition is achieved through the built-in digital camera on the Orange Pi, which operates independently and is unaffected by the digital or analog video stream received by the pilot. This ensures that the target recognition process remains functional even if the pilot's control interface experiences disruptions or delays. By utilizing the capabilities of the Orange Pi, the UAV can effectively analyze the visual data in real-time, allowing for accurate identification and tracking of targets without relying on the operator's video feed. This independence enhances the UAV's operational resilience and allows for more robust mission execution in various environments.

IV. Conclusions

Implementing a dedicated computing unit, such as an Orange Pi, enhances the UAV's ability to autonomously navigate and execute missions in the event of signal loss. By utilizing data from onboard sensors and artificial intelligence, these systems can effectively maintain flight stability and target acquisition, even in the absence of operator input.

The integration of robust failsafe mechanisms, advanced computing power, and intelligent navigation strategies presents a promising approach to mitigating the risks associated with signal loss in UAV operations. This comprehensive strategy not only enhances the reliability of UAVs but also expands their operational potential across diverse environments, making them valuable assets in both civilian and military contexts.

Future research and development should focus on refining these systems, exploring new algorithms for autonomous decision-making, and improving the resilience of UAVs against various types of interference. As technology continues to evolve, ensuring that UAVs can operate safely and effectively remains a priority for developers and operators alike.

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