Autonomous Drones

Divya B V, Anup Rao K, Ashish K Jacob, Vaishnav Pramod and Pattabi Ram
School of Electrical & Electronics Engineering, REVA University, Bangalore, India

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Abstract: This paper presents an innovative and cost-effective approach to autonomous drone systems, utilizing microcontroller-based signal mimicry achieved through PWM signal analysis and recreation. The study investigates the feasibility and effectiveness of this technique, demonstrating its potential for applications in surveillance, logistics, disaster response, and environmental monitoring. By leveraging microcontrollers, the system offers adaptability, scalability, and seamless integration with existing infrastructures, catering to diverse operational needs. This paper contributes to the advancement of autonomous drone technology, showcasing the potential of microcontroller-based signal emulation for cost-effective and adaptable drone control. Additionally, emphasis is placed on the transformative potential of autonomous drone systems, highlighting their capabilities in real-time data acquisition, machine learning, and collaborative swarm intelligence across various industries.

1 INTRODUCTION

The exploration of autonomous drone control methods has led to the investigation of integrating microcontroller-based signal mimicry. This research delves into various aspects of autonomous drones, focusing specifically on Raspberry Pi Zero and other cost-effective components. A comprehensive investigation encompasses real-world performance, adaptability, ethical considerations, and the unique contributions of autonomous drone systems.

Various studies contribute to the advancement of autonomous drone technology. Research on altitude control algorithms and measurement fault diagnosis provides essential insights for ensuring the effectiveness of autonomous drone systems (Mung and Lee, 2016), (Mung and et al. , 2017). Work on deep reinforcement learning for navigation aligns with the emphasis on innovative approaches in autonomous drone control discussed in this paper(Hodge, Hawkins, et al. , 2017). Investigations into GNSS-based systems for delivery drones highlight the importance of efficient navigation techniques, relevant to the applications discussed in this study (Hodge, Hawkins, et al. , 2017). Additionally, proposed strategies for safer navigation complement the focus on cost-effective and adaptable drone control presented in this paper. These studies collectively contribute to the progress of autonomous drone technology, providing insights and solutions that align with the objectives and findings of this research.

This section explores the construction of the experimental drone and the process of reading and analyzing the signals generated by the transceiver. It begins by outlining the conventional quadcopter configuration, followed by a detailed description of the components employed in the drone construction, including information on the motors, electronic speed controllers (ESCs), frame, propellers, and flight controller. Additionally, details regarding the transmitter and receiver used for wireless control of the drone are provided.

Following the construction details, the intriguing process of analyzing the transceiver's signals is explored. Here, the Arduino UNO, a versatile microcontroller, is leveraged to capture and interpret the signals with accuracy. Discussion focuses on the specific PWM pins utilized and their frequencies, emphasizing their role in capturing crucial information. A block diagram is presented to visually represent the signal processing pipeline and how the signals are received and processed by the Arduino.

The analysis extends beyond simply capturing the signals. It demonstrates how to effectively read and interpret these signals using the Arduino UNO's

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capabilities and a well-conceived approach. This paves the way for subsequent analysis and decision-making, enabling the extraction of valuable information and precise control over the drone's movements. The process is showcased through figures depicting the signal behavior when the transceiver is turned on and off, as well as how the signal alters with adjustments to the throttle on the controller. Such analysis is crucial for ensuring optimal performance and identifying any potential issues with the control system.

2 QUADCOPTER CONSTRUCTION AND PROBLEM FORMULATION

Quadcopters, a prominent type of UAVs, have captured researchers' interest due to their exceptional features. These include high maneuverability, reliability, versatile applications, and cost-effectiveness. With their four rotors arranged symmetrically, quadcopters excel in navigating complex environments with precision. Their compact size and straightforward design make them ideal for various tasks such as aerial photography, surveillance, search and rescue missions, and package delivery. This versatility and efficiency make quadcopters a compelling choice for both research and practical applications (Ozbek, Onkol, Garcia, 2018).

Various studies explore advancements in autonomous drone technology. One study introduces an optimization framework for vision-based autonomous drone navigation, enhancing tasks like surveillance and environmental monitoring (Navardi, Shiri, et al. , 2016). Another research effort focuses on autonomous drone delivery systems, potentially revolutionizing last-mile logistics (Kannan;, Min, Hong, 2019). A separate study discusses continuous maneuver control and data capture scheduling of autonomous drones in wireless sensor networks, aiming to optimize data acquisition efficiency(Li, Ni, Hong, 2019). Additionally, a proposed resource-efficient online target detection system utilizes autonomous drones, enhancing IoT applications (Wang, Gu, et al. , 2020). Furthermore, research examines the stability of small-scale UAVs under PID control with added payload mass, contributing to the understanding of drone stability (Pounds, Bersak, et al. , 2019). Another study discusses resilient control design for intelligent vehicle lateral motion regulation, offering insights applicable to drone control systems (Chang, Liu, et al. , 2017). Finally, visual servoing techniques for micro quadrotors landing on ground platforms are explored, addressing challenges in drone precision landing (Huang, Chiang, et al. , 2022).

In this section of the paper, the investigation into autonomous drone control methods delved into the integration of microcontroller-based signal mimicry. Various aspects of autonomous drones were explored, focusing on Raspberry Pi Zero and other inexpensive components. The findings cover real-world performance, adaptability, ethical considerations, and the unique contributions of autonomous drone systems.

In this section, the construction of the drone for experimentation and reading the signals created by the transceiver for recreation will be briefly discussed.

2.1 Drone Construction

In this Subsection, Figure 1 depicts the conventional quadcopter configuration, comprising four rotors mounted on arms extending from a central body. Each rotor is powered by a brushless DC (BLDC) motor, generating downward thrust forces to achieve vertical lift. The magnitude and direction of the thrust forces are adjustable by varying the motor speeds.

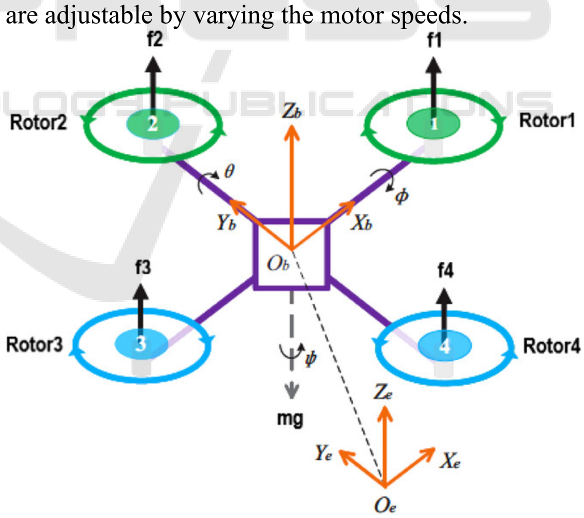

Figure 1: Quadcopter Configuration

The drone system employed for our experimentation utilized cost-effective components to minimize expenses. The motors were 1000 RPM/Volt BLDC motors, known for their high power and efficiency. To control the motor speeds, four electronic speed controllers (ESCs) were utilized. The drone frame was an f450 model, commonly preferred by DIY drone builders. Plastic propellers were chosen for their combination of lightness and durability. The flight controller was a KK2.1.5 model, a popular open-source option. Lastly, for wireless control of the drone, a Flysky transmitter and receiver were used.

Figure 2: F450 drone frame and 1000 RPM/Volt BLDC motor used in the construction of the drone

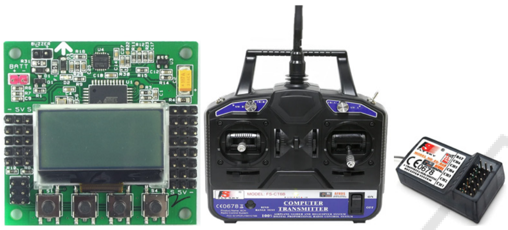

Figure 3: KK2.1.5 Flight Controller for stability of the system and Flysky transmitter and receiver used further down in section B

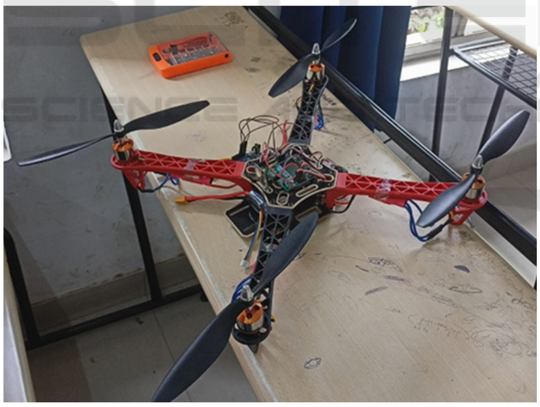

Figure 4: The experimental quadcopter drone, used for experimentation and further research.

The constructed drone system is capable of executing various maneuvers, including hovering, forward and backward flight, and left and right turns. It exhibited stability and ease of control, even in windy conditions.

2.2 Reading Receiver Signal

In this section, the procedure of analyzing the signals generated by the transceiver of the drone system will be investigated and examined. To accomplish this, the Arduino UNO, a versatile microcontroller known for its widespread use in various DIY projects, was employed.

Specifically, designated Pulse Width Modulation (PWM) pins on the Arduino UNO, including pins 3, 5, 6, 9, 10, and 11, were utilized for capturing and interpreting the signals transmitted by the transceiver with accuracy. These PWM pins have frequencies of 490 Hz, except for pins 5 and 6, which have frequencies of 980 Hz. They are essential for capturing and interpreting the signals transmitted by the transceiver accurately.

Figure 5 presents a simplified block diagram illustrating the flow of PWM signals from the transceiver to the Arduino UNO. This diagram serves as a visual representation of the signal processing pipeline, facilitating a comprehensive understanding of how the signals are received and processed by the Arduino

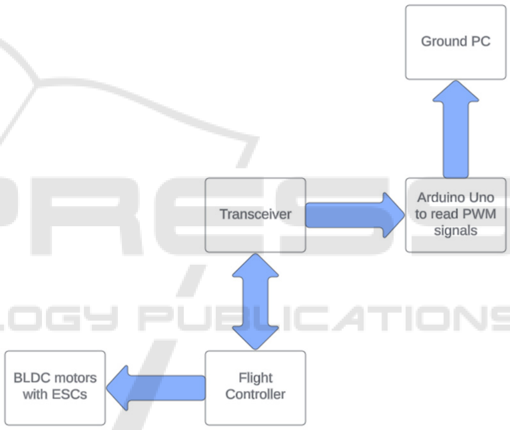

Figure 5: Block Diagram of the Basic Reading Process of a Transceiver Signal

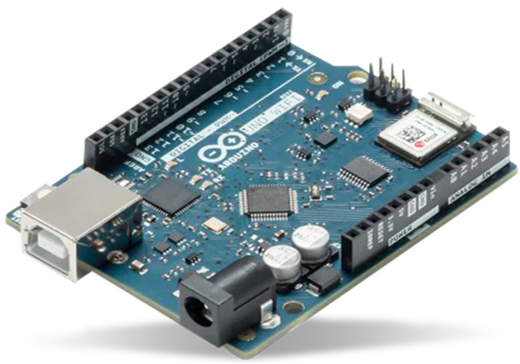

Figure 6: The Arduino UNO is able to read pulse width modulation (PWM) signals emanating from the transceiver.

3 MAIN RESULT

3.1 Signal Analysis

By strategically leveraging the capabilities of the Arduino UNO and employing a well-conceived approach to signal acquisition, one can effectively read and interpret the signals produced by the transceiver of the drone system. This lays the foundation for subsequent analysis and decision-making, enabling the extraction of valuable information and precise control over the drone's movements.

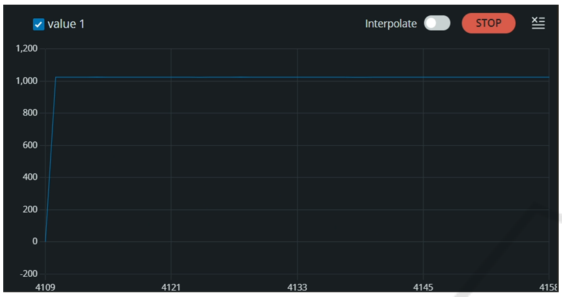

Figure 7: Detection of the signal when the transceiver was turned ON.

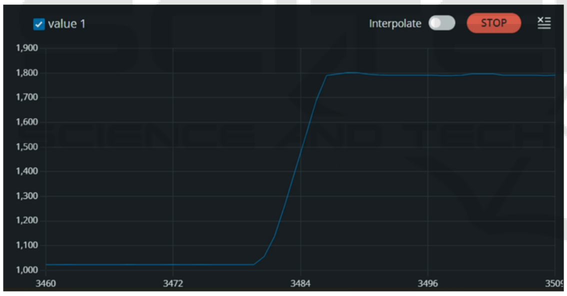

Figure 8: Alterations in the signal when the throttle on the transceiver was adjusted to the maximum.

The analysis presented in Figures 7-11 focuses on channel 2, corresponding to the throttle of the drone controller. This involves capturing and plotting the signal over time to understand its behavior.

The y-axis represents the signal, while the x-axis represents time. The graph visually illustrates how the signal changes in response to movements of the remote controller stick, allowing assessment of throttle channel stability, responsiveness, and overall performance.

Similar analyses are conducted for all four channels of the transceiver. By comparing signal-to-time graphs of different channels, any discrepancies or inconsistencies in behavior can be identified. This ensures optimal functioning of all channels and the drone controller.

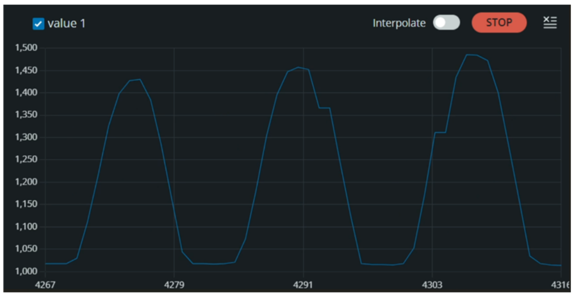

Figure 9: Alterations in the signal as the throttle on the transceiver was varied in an upward and downward direction

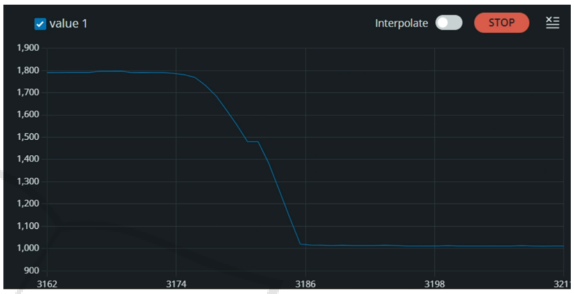

Figure 10: Alterations in the signal when the throttle on the transceiver was adjusted to the minimum.

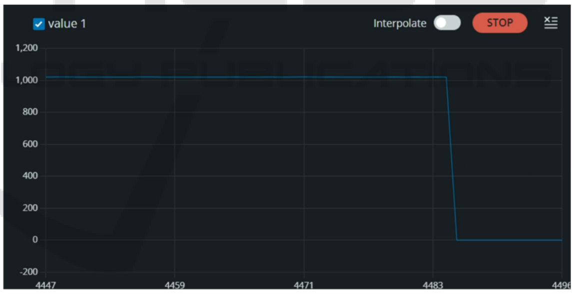

Figure 11: Changes seen in the signal when the transceiver was turned OFF.

Channel 2 analysis provides insights into throttle control, showing how the signal modulates to adjust the drone's speed and altitude. Evaluation includes assessing throttle response smoothness, presence of sudden signal changes, and overall control system stability.

Analyzing all channels' signal-to-time graphs offers a comprehensive understanding of the drone controller's performance. This analysis is essential for optimizing controller behavior and ensuring reliable drone operation.

In summary, examining Channel 2 involves capturing and graphically representing the signal over time to assess throttle channel performance. Similar analyses across all channels aid in identifying discrepancies and optimizing controller behavior for efficient drone operation.

3.2 Recreation

In this section of the project, the process of achieving simple automation of a quadcopter by analyzing the signals produced by the transceiver and recreating them using a microcontroller is delved into. This approach aims to provide a cost-effective and customizable solution for controlling the quadcopter without relying on expensive commercial remotes.

To accomplish this objective, the Raspberry Pi Zero microcontroller was utilized, widely recognized for its adaptability and extensive application in DIY projects. The Raspberry Pi Zero serves as the central processing unit of the automated system, interpreting signals received from the ground personal computer (PC) of the transceiver and generating appropriate control commands for the quadcopter, as depicted in Figure 12.

The process began with thorough analysis of the signals transmitted by the transceiver. Using the Arduino UNO and its PWM pins, specific patterns and frequencies associated with different control inputs, such as throttle, yaw, pitch, and roll, were identified. This analysis provided an understanding of the communication protocol between the transceiver and the quadcopter.

Based on the signal analysis, a Python script was developed to emulate the transceiver's signals. The script generates PWM signals with varying duty cycles, corresponding to the desired control inputs. The Raspberry Pi Zero's GPIO pins are utilized to output these PWM signals, providing precise control over the quadcopter's movements.

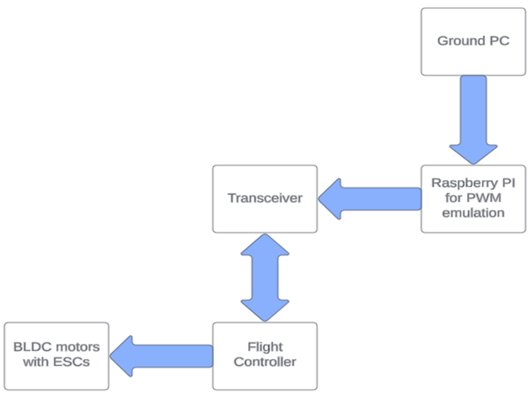

Figure 12: Block Diagram of the Basic emulating Process of the Transceiver Signal

By combining signal analysis with microcontroller emulation, simple automation of the quadcopter was achieved. This method offers a flexible and cost-effective alternative to commercial remote controls, enabling customization and integration with other systems.

4 CONCLUSION

Our investigation into microcontroller-based autonomous drone systems yielded promising results, demonstrating the feasibility and effectiveness of this approach. A cost-effective drone was successfully constructed using readily available components, and our process for reading, analyzing, and emulating the transceiver signals was established. This enabled the achievement of basic automation of the quadcopter through the Raspberry Pi Zero microcontroller, serving as a customizable alternative to traditional remote controls.

The key findings of our study can be summarized as follows:

Effective signal analysis and emulation: The Arduino UNO was successfully employed to capture and interpret the transceiver signals, paving the way for their subsequent emulation using the Raspberry Pi Zero.

Cost-effective and adaptable solution: The use of readily available components and our microcontroller-based approach offer a cost-effective and adaptable solution for autonomous drone control compared to traditional methods.

Potential for diverse applications: The developed system lays the groundwork for further exploration and potential applications in various fields, including surveillance, logistics, disaster response, and environmental monitoring.

While this paper focused on basic automation, it serves as a valuable stepping stone for further development of autonomous drone systems. Future research can explore more complex maneuvers, integrate sensor data for environment awareness, and investigate the application of machine learning algorithms for enhanced decision-making capabilities. Additionally, ethical considerations regarding data privacy, safety, and responsible drone use must be continually addressed as the technology advances.

In conclusion, this paper has demonstrated the potential of microcontroller-based signal emulation for cost-effective and adaptable autonomous drone control. This technology has the potential to significantly impact various industries and pave the way for innovative solutions in the future of drone technology.

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