ECE 445 Team 64 Project Proposal:
First-Person View Drone

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1. Introduction

1.1 Problem

The University of Illinois Center for Autonomy Lab is faced with the challenge of developing a replicable FPV drone that can partake in in-lab races while being precisely tracked using Vicon motion capture technology. Traditional FPV racing drones tend to be quite large and are therefore not compatible with the small space of the drone arena. The objective is to create a system that allows for the comparison of flight paths and the collection of motion data to determine the most efficient navigational strategies. This endeavor will not only contribute to research in drone autonomy but also enhance the lab's engagement with drone technology through the excitement of competitive racing.

1.2 Solution

To address the unique requirements of the University of Illinois Center for Autonomy, the proposed solution involves the development of a custom-designed FPV drone, built upon the Crazyflie drone platform. This enhanced drone will be equipped with a sophisticated camera subsystem, capable of transmitting a real-time visual feed to a head-mounted display. Additionally, it will display accelerometer and altitude data, offering the pilot an immersive navigational experience. To support this, custom PCBs will be fabricated to integrate the necessary electronic components, ensuring seamless operation between the transmitter, receiver, and the headset. Moreover, the solution incorporates the utilization of the Vicon motion capture system, enhanced by specially designed infrared LEDs, to facilitate accurate tracking of the drones during flight. This system will enable the analysis of flight efficiency and path optimization and increase the accessibility and interest in drone technology through the exhilarating arena of drone racing.

1.3 Visual Aid

The visual schematic for the FPV drone system features the compact Crazyflie drone, equipped with a high-definition camera capable of capturing and transmitting vivid aerial footage. Adjacent to the drone is the FPV headset, a critical component for the immersive piloting experience, showcasing the 'Fat Shark' goggles renowned for their clarity and responsiveness. Essential to the system's functionality are the antennas, depicted to highlight their role in maintaining a strong and stable connection between the drone and the headset. This visual aid underscores the interconnectivity and synergy of the components, which together form the backbone of a state-of-the-art FPV drone racing setup.

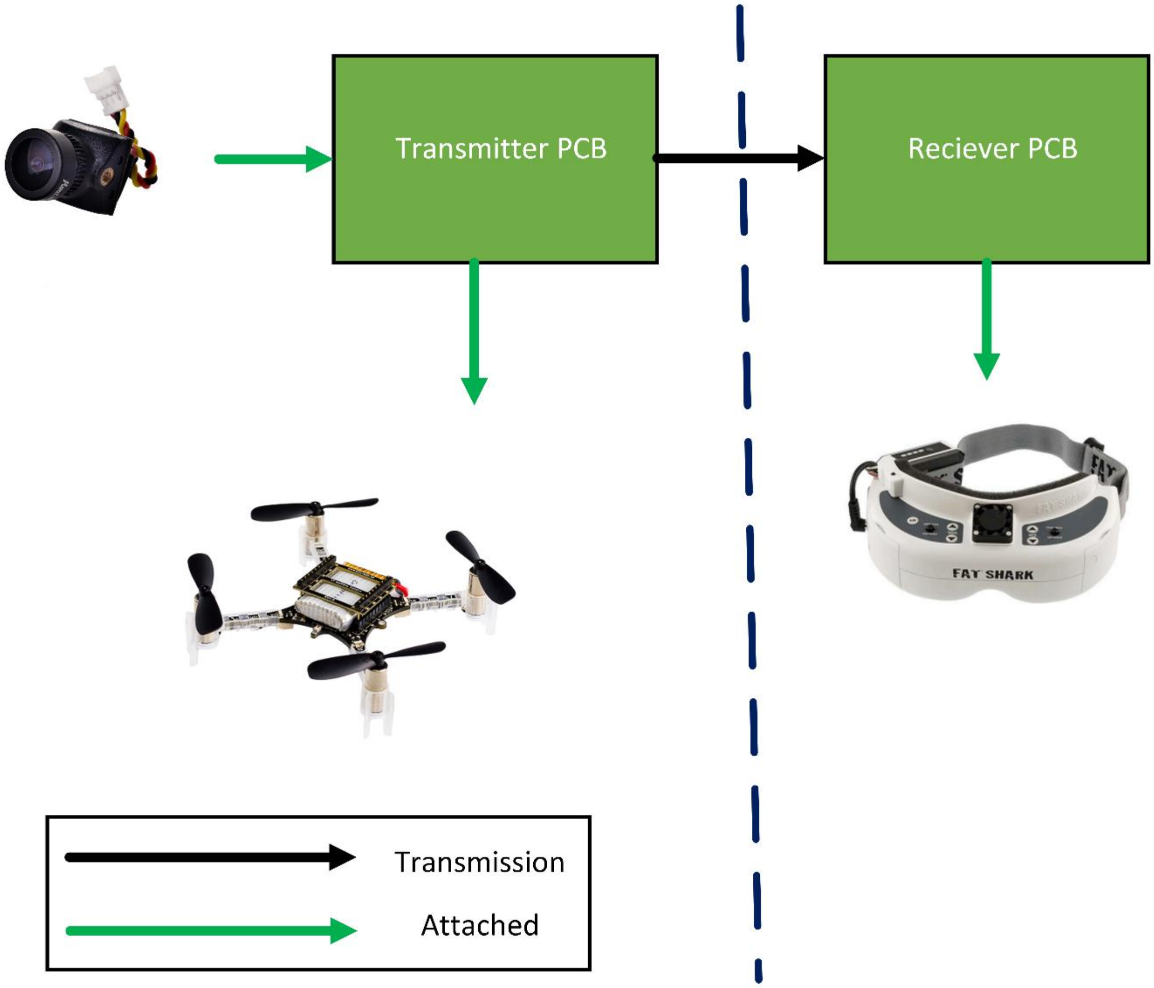

Figure 1: Visual Aid for the FPV Drone

1.4 High Level Requirements

1) The drone shall maintain stable flight dynamics when equipped with additional hardware, ensuring controllability with a maximum deviation of 5% from expected flight paths under standard test conditions. This will require the total additional weight added to the drone to be balanced and less than 15g.
2) The camera system shall stream high-definition video to the FPV headset with zero perceptible interruptions, maintaining a latency of at least 30 Hz to ensure an immersive real-time experience. The video display shall overlay sensor data from the drone, including from the altimeter and the accelerometer.
3) The Vicon motion capture system shall be leveraged to enhance drone tracking capabilities, with infrared LED markers ensuring continuous and accurate positioning data within the flight area.

2. Design

2.1 Block Diagram

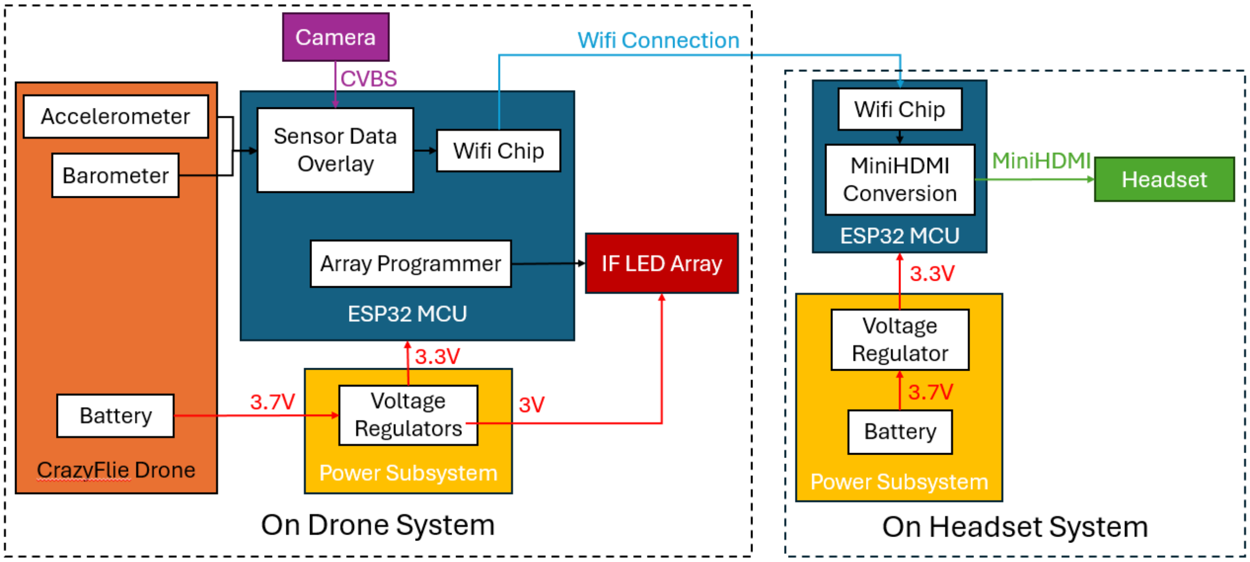

Figure 2: Block Diagram of the Proposed System

2.2 Subsystem Overview

Infrared LED Subsystem:

This subsystem is dedicated to ensuring accurate tracking within the Vicon motion capture environment. It consists of high-intensity infrared LEDs that emit signals captured by the Vicon system's cameras. The LEDs are strategically positioned on the drone to provide a 360-degree visibility profile, crucial for precise localization during flight. Each LED is driven by a current-regulated driver circuit, allowing for consistent output levels that are crucial for reliable tracking. The subsystem is designed to be low-power yet effective, ensuring minimal impact on the drone's overall battery life. The LED array will be programmable so that a distinct pattern can be emitted and thus a drone can be distinguished by the Vicon system.

Camera Subsystem:

The camera subsystem features a compact RunCam Nano 2, known for its exceptional 700TVL resolution and expansive field of view of up to 170 degrees. This CMOS FPV camera is calibrated for the PAL system and is equipped with a 1.8mm lens, providing crisp and wide-angle visuals essential for FPV racing. The camera is directly interfaced with a control unit that allows manual adjustments of exposure and focus settings to ensure optimal image quality under variable lighting conditions and dynamic flight maneuvers. The camera's fixed mounting ensures a reduced footprint and weight on the drone, allowing for agility and prolonged flight times.

Microcontroller Subsystem:

This subsystem's 3 primary roles are to integrate sensor and camera data into one data stream, handle the wireless communication between the drone and the FPV headset, and control the LED array. It includes an ESP32 chip onboard the drone that sends the live video feed and an ESP32 integrated into the FPV headset. We will also use the ESP32 on the drone to integrate sensor data into the video feed, so the finalized video feed will be transmitted over Wi-Fi.

Vicon Subsystem:

This subsystem integrates with the drone's onboard sensors and the external Vicon motion capture setup to provide precise positional data. The Vicon cameras capture the infrared LED signals from the drone, and the corresponding software computes the drone's location in three-dimensional space. The subsystem includes calibration tools to ensure that the Vicon system's spatial readings are accurate and reflective of the drone's actual movements. The data from this subsystem is critical for analyzing flight paths and optimizing drone performance.

Headset Subsystem:

The headset subsystem is centered around the Fat Shark FSV1074 Dominator HD2[1] goggles, which are equipped with a high-resolution display to render the video feed from the drone's camera with clarity and depth. These goggles are selected because they are what the Center for Autonomy has to offer. The onboard receiver decodes the incoming HDMI video signal with minimal latency.

2.3 Subsystem Requirements

Infrared LED Subsystem:

1. The LEDs must emit a wavelength of 850nm with a tolerance of ±10nm to ensure compatibility with the Vicon system's tracking capabilities.
2. The LEDs should be individually controllable to emit distinct patterns.

Camera Subsystem:

1. The RunCam Nano 2 must deliver a resolution of 700TVL with a minimum illumination of 0.01 lux, ensuring clear image capture even in low-light conditions.
2. The camera's field of view must be no less than 155 degrees to provide a broad visual range necessary for FPV flight.

Microcontroller Subsystem:

1. The transmitting ESP32 must maintain a stable signal with a range of at least 30 meters, ensuring consistent video feed transmission during flight in the flight arena.
2. The receiving ESP32, integrated into the Fat Shark headset, must decode the incoming signal with a latency of at least 30 Hz to ensure real-time response.

Vicon Subsystem:

1. The Vicon system must track the drone's position with an accuracy of at least 99%, ensuring precise data for flight path analysis.
2. The system should process and store position data to later display the flight path taken during flight

Headset Subsystem:

1. The headset must be capable of interfacing with a compatible HDMI receiver to display the video feed from the drone's camera system.
2. It should provide an immersive viewing experience void of flickering.

2.3 Tolerance Analysis

One important area of tolerance our project must meet is power consumption on the drone. We plan to use the built in battery on the Crazyflie drone with a capacity of 350mAh that outputs at 3.7V, with maximum sustained output of 5.25A. The drone consumes 100mA while stationary and ~7W when flying unburdened at 27 grams. The camera weighs 2.5 grams, and we can assume the ESP32/ PCB combo weighs around 10 grams or less. As a rough approximation if we assume power grows quadratically with weight we would expect simply carrying the components to consume around 15W, which at 3.7V is 4.05A.

The camera consumes 120mA, and we can assume the ESP32 and LEDs will consume 400mA total. Combining that all together we have a total expected consumption of 4.57A, below the max capacity of 5.25A. We would expect it to have a total battery life of 4:30 of flight.

3. Ethics and Safety

Our project's mission is to harness advanced drone technology to enhance the educational and research capabilities of the University of Illinois Center for Autonomy. We are committed to upholding the highest ethical standards and ensuring the safety of all involved, aligning with Section 1.1 of both the ACM and IEEE Ethical Codes.

3.1 User Risk and Bystander Risk

The operation of FPV drones entails inherent risks, such as equipment failure, control signal loss, or navigational errors, which can lead to property damage or injury. To mitigate these risks, strict operational protocols are established, including restricted access to the flight arena during drone operation and the installation of safety nets. Furthermore, rigorous pre-flight checks are enforced to ensure the drones' reliability and safety.

3.2 Equipment Safety and Regulation

All electronic components, including transmitters, receivers, and batteries, adhere to industry safety standards and regulations. The battery systems, in particular, are designed with multiple layers of protection against overcharging, short-circuiting, and thermal runaway. All batteries will be charged in certified packaging to reduce fire risk. We also ensure that the ESP32 Wi-Fi transmission power complies with FCC regulations to avoid interference with other devices and communication systems.

3.3 Data Processing and Privacy

While our project does not currently involve the storage or transmission of personal data, we recognize the importance of privacy in systems that collect and process environmental data. All team members are required to respect user privacy, complying with relevant data protection laws and the ethical guidelines outlined in section 1.6 of the ACM Code of Ethics

3.4 Personal Responsibility

Each team member is responsible for upholding ethical practices throughout the project's lifecycle. This includes a commitment to transparency, accurate reporting of data, and a refusal to manipulate test results or compromise on the quality and safety of our work. Our conduct is guided by the principles of honesty, integrity, and accountability, which are essential for maintaining the trust and credibility of our project.

References

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