Ford Motor Company AeroSearch

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***Abstract*—We prototyped an affordable drone to quickly scan populated areas to find lost pets, people, and any other objects using a real-time processing computer vision system. Our project was motivated by a lack of an effective go-to option for pet owners with escaped/lost pets. We constructed a ~6 inch drone equipped with a Raspberry Pi Zero microcontroller and a Raspberry Pi AI camera with a neural chip to perform fast onboard object detection, and we used the popular ArduPilot software for manual and automated flight control**

***Keywords—drone, autonomous flight, object detection** (key words)*

I. Project Overview (Background)

This project explores the development of an autonomous drone capable of searching for and identifying specific target objects such as pets, cars, people, or items. It combines lightweight yet powerful hardware with advanced software and machine learning (convolutional neural networks) for real-time computer vision and end-user feedback. Over the course of six months, we've produced a prototype unmanned aerial vehicle (UAV) to house and operate a camera with onboard object detection.

Gantt Chart (green = complete, yellow = in progress)

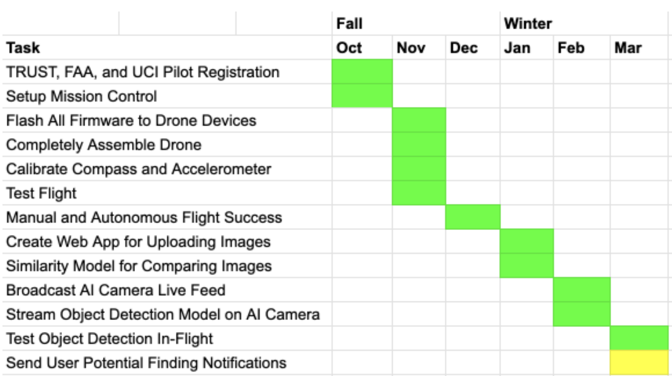

Fig. 1. *Gantt Chart*

II. Objectives

A. Overall Objectives

The primary objective of this project is to design an affordable drone capable of autonomously searching designated zones for target objects while notifying end-users of detected matches in real time. To achieve accessibility, the drone must be built with minimal costs and materials without compromising functionality. During the first half of this project, the focus was on soldering all parts together and constructing a fully operational drone capable of both manual and autonomous flight. This phase also included extensive testing of its manual and autonomous flight capabilities. During the final half of the project, we've implemented a real-time object detection model onboard the drone through the use of a raspberry pi and the newly released Raspberry Pi AI Camera. Additionally, we have developed the front end user interface through HTTP requests, allowing the user to view the live feed. Further optimization of the drone's performance is planned to prepare it for practical, real-world applications.

In terms of meeting our development goals, we achieved most of what we set out to do: the drone was successfully constructed and is capable of manual and autonomous flight piloted by an FAA certified pilot [5]; we trained, quantized, and packaged an object detection model onto the Pi AI Camera[9]; and we trained a machine learning similarity model to compare and contrast different images of dogs against the Stanford Dog Database.

We didn't meet all our goals due to time constraints. We did not develop a pinging or match success system with the front end like we'd hope to. This success system would have just been a quality of life improvement. Our energy was focused on developing and testing our object detection model to ensure it was accurate and fast enough for in-flight processing.

III. Setup Details for Project

A. Software Used

- ArduPilot — Drone Flight Control
- Image cosine similarity — Object similarity score

- OpenCV - Image processing in the detection pipeline
- Raspberry Pi AI Camera built-in model
- Python scripts — Object detection and drone-user interaction

B. Hardware Used

- Raspberry Pi Zero 2 W
- Raspberry Pi AI Camera
- 5 Pairs XT60 Plug Connector Female and Male with 14 AWG Silicon Wire
- 12 Pair XT60H (XT60 Upgrade) Male Female Bullet Connectors
- 2 Pair No Wires XT30 to XT60 Plug Female Male Adapter
- MATEK F405-WMN Flight Controller
- Tiger Motors T-Motor F1404 (2900KV/3800KV/4600KV)
- Gemfan Hurricane 4024 2-Blade Props
- Zeee 2S Lipo Battery 2200mAh 7.4V 50C
- Hobby Fans B6 Mini Professional Balance Charger/Discharger
- DerBlue Fireproof Explosionproof Lipo Battery Safe Bag
- Wolfwhoop WT07 Micro 5.8GHz 25mW FPV Transmitter and 600TVL Camera
- SoloGood 4.3" FPV Monitor with DVR
- DIYmalls BE-880 GPS Receiver Module
- Happymodel 2.4GHz ExpressLRS EP1 Nano Long Range Receiver
- FLY RC Cellmeter 7 Digital Battery Capacity Checker
- Seeed Studio XIAO ESP32C3 Tiny MCU Board

IV. Standards Used or Considered

- IEEE — Industry standard wiring, voltage, and current regulation, safety practices
- TCP — Drone-user communication protocol
- FAA — Standards and safety regulations for flying UAVs

V. Security Considerations

Since the drone connects to public frequencies, our drone faced the risk of accidentally connecting to the same connection frequency as other drones, which would allow them to control our drone or cause signal interference. To mitigate this risk, we changed our communication frequency from the default and communicated with design teams nearby in our flight test zones to ensure that our frequencies were different.

For physical security, we must follow all flight guidelines under the part 107 rules. This includes all pilots being FAA and TRUST certified, keeping flight below posted flight zone altitudes in controlled airspace, flying below 400 feet in class G airspace, maintaining visual line of sight of the drone while flying, and giving way to and not endangering public aircraft [10].

Additionally, our team faced a significant security risk when connecting a Raspberry Pi to school Wi-Fi. When registering a device to the school's Wi-Fi system, the password to connect to the device is the same for all students by default, meaning that if we did not change the password immediately, a malicious student could connect to our Raspberry Pi and do actions that would cause the Pi to be banned by UCI's security system. If banned, the Pi, along with all other devices registered under the student's name, could be blacklisted from the school's Wi-Fi. To address this concern, the team member who registered the Pi to the school's Wi-Fi promptly changed the password required for the Pi to connect to the Wi-Fi.

VI. Prototypes

Week 1: Reviewed safety regulations (FAA, UC).

Week 2: Installed and programmed flight controllers.

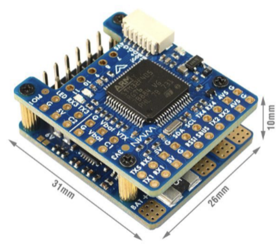

Fig. 2. *Flight controller top view [1]*

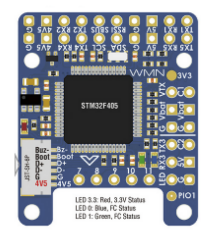

Fig. 3. *Flight controller diagram [6]*

Week 3: Configured radio controls.

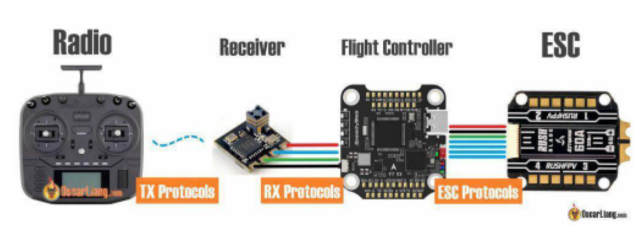

Fig. 4. *Radio and receiver connection with flight controller [4]*

Week 4: Set up power systems and ESCs for motor control.

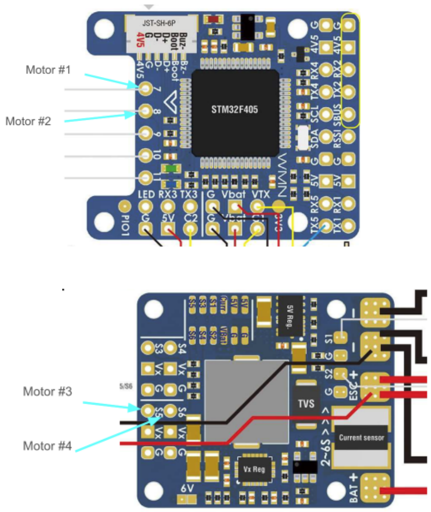

Fig. 5. *Flight controller motor wiring (PWM ports) [6]*

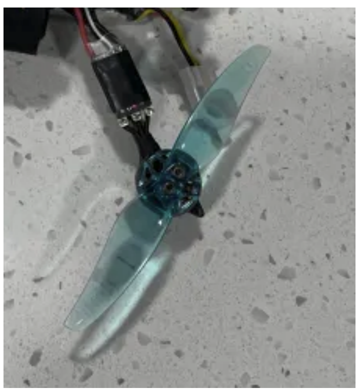

Fig. 6. *Motor, propeller, and ESC on our drone*

Week 5: Integrated GPS.

Fig. 7. *GPS Installed on our drone*

Week 6: Researched and purchased Raspberry Pi AI Camera

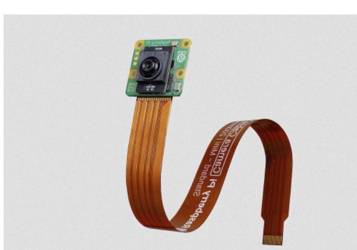

Fig. 8. *Raspberry Pi AI Camera [9]*

Week 7: Maiden manual flight tests in the drone cage.

Fig. 9. *Drone in cage, engaging motors and FPV camera feed*

Week 8: Established telemetry connection using ESP32 and DroneBridge.

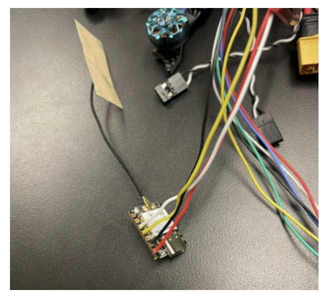

Fig. 10. *ESP32 soldered and connected on our drone*

Week 9: Configured mission planner for autonomous flight.

Fig. 11. *ArduPilot mission planner waypoints*

Week 10: Conducted autonomous flight in open airspace

Week 15: Live video stream from AI camera accessible in web browser.

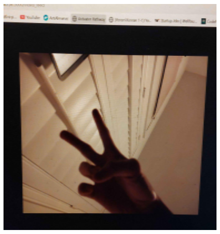

Fig. 12. *Camera feed streaming test*

Week 16: Model training and validation reports

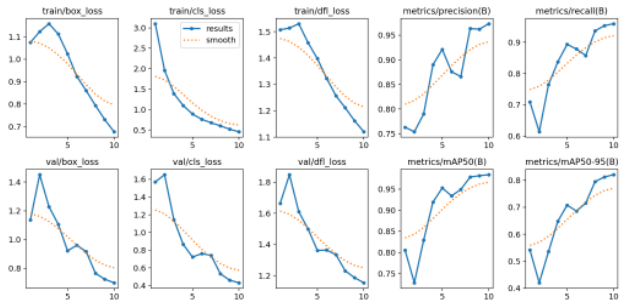

Fig. 13. *Graphs of training loss scores for similarity model*

Week 17: Mounted AI camera and Raspberry Pi on drone.

Fig. 14. *Completed drone with camera attachment*

Week 18: In-flight object detection

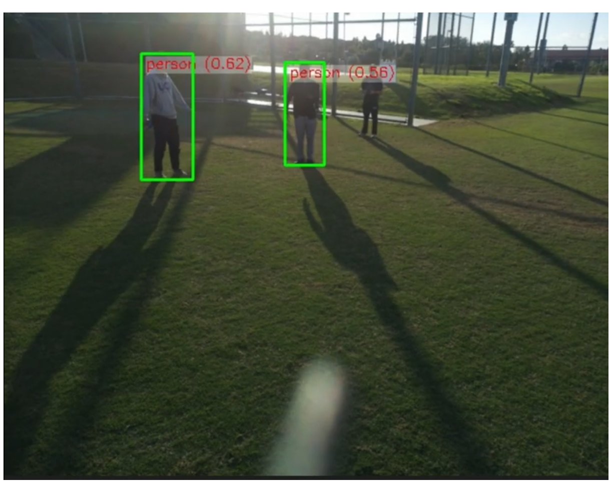

Fig. 15. *Object detection stream screenshot while drone is flying*

VII. Experimental Results (So Far)

Experiments/Results So Far

Calibration: Successfully passed calibrations and safety measures from the FAA and our advisor, Prof. Peter Burke

Manual Flight: Successfully flown and stabilized using radio controls.

Autonomous Flight: Achieved waypoint-based navigation and return-to-launch in controlled environments.

Object Detection Model: Successfully trained and tested a custom object detection model meant for dogs and cats

Object Detection through Camera Feed: The model could successfully find dogs, cats, humans, etc. through the camera feed with a confidence score of over 50%.

In-flight object detection: The model successfully captured instances of humans while in flight in real-time.

Preliminary results show that the drone can:

- Execute manual and autonomous flights with full data feedback and geofence for safety if the drone does not respond to missions correctly.
- Survey an area and scan for objects while in-flight

Future Work

To enhance detection accuracy, fully implement object similarity models such as siamese or triplet networks. Develop user-friendly software that enables seamless interaction with the drone, ensuring intuitive control and real-time feedback. Integrating long-range transmitters for the Pi AI Cam (Radio or WiFi) is also a goal that will greatly increase the working range of the drone. Additionally, explore integration with cloud-based data pipelines to facilitate real-time updates, allowing for instantaneous processing and decision-making, while also enabling the storage and analysis of historical data for comprehensive analytics and performance optimization.

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