SharkSafeAI Embedded Aerial System for Offshore Recreational Safety

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***Abstract*—The convergence of advancements in Machine Learning and the rise of modern microcontrollers allows us to leverage the strengths of both in a unified system. Object Detection, an ML technique, utilizes a computer and camera to recognize pre-trained objects. Previously demanding substantial computing resources, these systems can now perform object detection efficiently using cost-effective microcontrollers. This integration seamlessly incorporates powerful ML capabilities into microcontroller-based systems that are both budget-friendly and resource-efficient.**

I. Introduction

THE SharkSafeAI system seamlessly integrates with various aerial platforms, offering reliable surveillance and precise identification of sharks through overhead camera monitoring. This system consists of an ESP32-CAM microcontroller, an aerial apparatus like a commercial drone, and utilizes the Edge Impulse web service for user interaction. The Edge Impulse platform facilitates the training and development of our machine learning model, which is subsequently exported to TinyML and executed on the ESP32 device for efficient and effective shark detection. Feb 03, 2024

II. Design

The SharkSafeAI system is specifically engineered for the general consumer, enabling them to conduct coastal surveys before swimming or intermittently monitor a designated area while others engage in water activities safely. The ESP32-CAM is intended for attachment to any aerial vehicle capable of operating within a 200-square-meter region around the targeted observation zone. This observation boundary is defined by the maximum WiFi signal strength emitted by the ESP32-CAM from the position of the aerial drone.

It is crucial to acknowledge that this distance is susceptible to fluctuations and influenced by diverse operational conditions. The development utilized a commercial drone with the capacity to support both the camera and its accompanying battery. Upon positively identifying shark silhouettes, the system promptly triggers an alert sent to the user's mobile device.

A. Inspirations

Motivation for the development of the SharkSafeAI system was drawn from alarming news coverage depicting instances of sharks in close proximity to swimmers along the California coast. Additionally, inspiration was garnered from the DroneBot Workshop's YouTube channel, renowned for its extensive collection of do-it-yourself (DIY) project tutorials, particularly those centered around microcontroller applications.

B. Goals

The primary objectives of this project encompass the establishment of a proof of concept and the creation of a functional prototype. This involves the development of a camera with specialized object detection capabilities, specifically concentrating on identifying shark silhouettes along coastlines. Subsequent goals include the integration of a tailored mobile application designed to complement the system, along with the creation of a 3D printed enclosure for housing the camera.

C. Software Design

We utilize the "eloquent-espcam32" library to unleash the full power of you ESP32 camera. This Arduino library kick starts the ESP32 camera projects by providing a set of tools to easily interact with the camera. Edge Computing is more viable today with the reduction in size provided by microcontrollers. Edge computing is a form of computing that processes data close to the source or at the "edge" of a network.

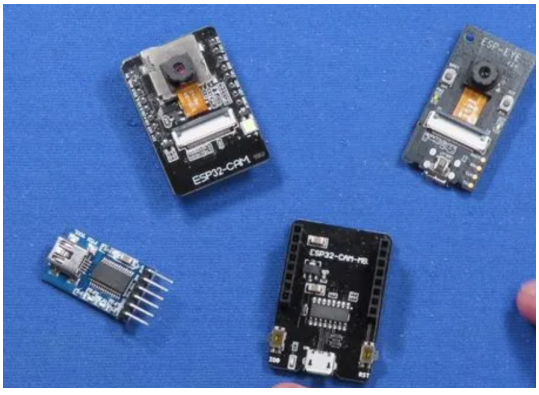

Fig. 1. ESP32-CAM and ESP-EYE hardware

By using low-cost microcontrollers, we can design a system that will identify specific objects which we can forward to the users mobile device via WiFi. Object detection is a field of computing that focuses on identifying objects within the cameras field of view.

Object Detection is really a combination of two separate technologies:

1. Object Classification pertains to the capacity to recognize

and categorize diverse objects within an image. This is achieved by furnishing a neural network with extensive training data consisting of labeled images, each corresponding to a specific object. Following thorough training, the program gains the ability to scrutinize new images and confidently identify these objects. The significance of Object Classification extends across various applications, such as robotics, healthcare, and defense, where it serves as a foundational element for accurate and efficient operations.

2. Object Localization complements Object Classification by not only identifying objects within an image but also providing precise location coordinates through the creation of a ”bounding box” around the target object. These systems excel in recognizing multiple objects simultaneously within the same image. The applications of Object Localization extend across various domains, including autonomous driving, robotics, and security systems, showcasing its versatility and importance in enhancing object identification and tracking capabilities.(dronebotworkshop)

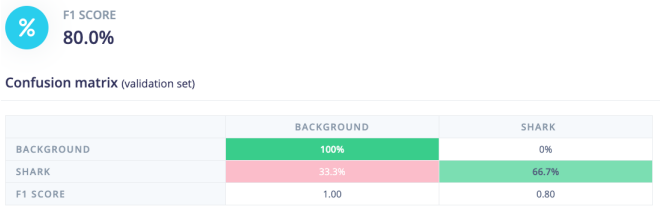

Fig. 2. Object Detection Confidence

III. Mechanics

Users have the flexibility to attach the ESP32-CAM to their privately owned drone or a comparable device, enabling manual flight over the designated observation area. This area is surveyed for silhouettes resembling that of a shark beneath the water. Upon identification of a shark, the ESP32-CAM initiates a push notification through its onboard WiFi network to the user's mobile device. This notification includes both the timestamp and the captured image for timely and informative alerts.

IV. Analysis

Significant enhancements to the system can be achieved by implementing a more robust camera housing. Improvements may include the addition of a physical barrier to shield the camera from salt and moisture prevalent in coastal environments, where the device is intended for use. Additionally, boosting signal strength through the incorporation of a 2.4GHz external antenna, soldered to the ESP32-CAM board, stands as a viable approach. This augmented range would notably enhance the system's overall utility.

Addressing a common issue with commercial drones—their limited ability to maintain continuous flight—can be accomplished by considering the utilization of power-tethered drones. However, it's noteworthy that the cost of these drones is 20-40 times higher than that of the average consumer drone.

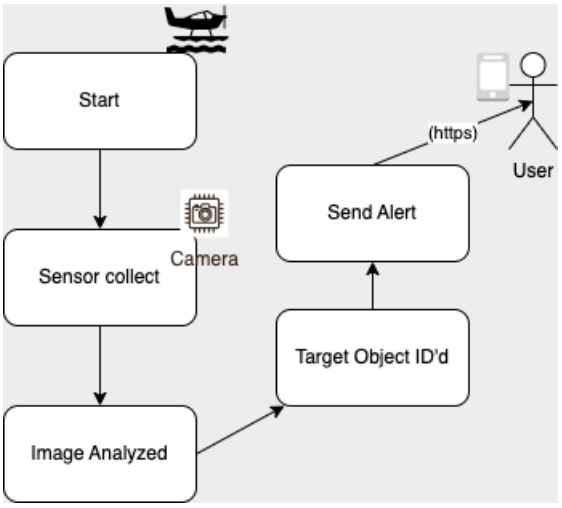

Fig. 3. System Flow Diagram

Another avenue for improvement lies in optimizing system performance.

Fig. 4. ESP32 Device Performance (estimate)

An evident observation is the inferencing time, which currently exceeds the desired threshold. Although this duration falls within the ESP32-CAM's operational limits, there is room for improvement in time utilization by refining our ML object detection model. Additionally, it's worth noting that the peak RAM usage is higher than typical for a model of this size. This elevation is attributed to sub-optimal training confidence scores, necessitating additional computations. Addressing and optimizing these aspects are key considerations for enhancing the overall efficiency of the system.

V. Conclusion

The functional design and cost-effectiveness of this system have proven to be robust and efficient in positively and confidently identifying specific target objects, specifically shark silhouettes against a marine background. Emphasizing lightweight construction, affordability, and minimal computing resource requirements, these design considerations are crucial for ensuring that the system is not only accessible to the average consumer but also practical to design and implement. The system has successfully achieved its objectives, demonstrated by the functional ESP32-CAM Object Detection software seamlessly integrating with a readily available aerial craft, effectively identifying target objects, and promptly alerting users via their mobile devices. Further refinement and customization of the system can be achieved through iterative improvements to the ML model, the incorporation of additional training data, and the development of a specialized housing to better protect the camera device.

VI. Citations

1. DroneBot Workshop. (2023). ESP32-CAM Object Detection with Edge Impulse. Retrieved from https://dronebotworkshop.com/esp32-object-detect/

2. Eloquentarduino. (n.d.). eloquentarduino/EloquentEsp32cam: Use your Esp32-cam like an expert. Retrieved from https://github.com/eloquentarduino/EloquentEsp32cam