12th of December 2025

Dear Dr. Tet Yeap, Sepideh Mousazadeh, and Futong Li,

Please find attached the end of term report entitled "Final Project Design Plan: Anti-Drone Mounting Defense System." This report is intended to outline the work done this semester by Groupe 105 towards their capstone project.

Enclosed you will find a summary of the project; including a summary of the problem being addressed, and overview of what we perceive is required to solve the problem. Following this introduction, we address our proposed solution based off the requirement specifications, and our system specifications. Finally ending with a potential business plan and proposed plan to complete the project next semester, with testing.

Thank you for your time and consideration.

Kind regards,

Christopher Wong, Duncan McRae, Isaac Soward, Leo Dionne

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ELG 4912

Final Project Design Plan

Anti-Drone Mounting Defense System

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EXECUTIVE SUMMARY

The contents of this report outline not only the potential, but the necessity for improved deterrent and defensive mechanism against increasingly popular drone attacks. Whether malicious or accidental, the dangers of drone technologies have become increasingly prevalent in todays society [1]. With the effect of drone attacks becoming dominant on the battlefield overseas, the dangers of malicious drone use in airports, large events or essential infrastructure, there begs the need for drones to be effectively intercepted. There are many strategies and technologies already at play in drone interception [2], [3], however many of these are prone to human error or impractical for civilian application. Our solution will passively and effectively target drones as they appear within unauthorized zones and provide a platform for modern intervention systems to dispose of dangerous drones in both military and civilian domains. By integrating a combination of the Voxel Movement Method and a trained Deep Learning Model YOLOv8, into a versatile pan-tilt camera system, we provide a platform for modern drone interception methods to autonomously target and remove dangerous drones.

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1. PROJECT DESCRIPTION

1.1. Principal Issue

Drones are becoming increasingly prevalent in modern society, with clear benefits in disciplines such as search and rescue or agriculture. However, they also create the clear potential for nefarious and harmful applications. One clear example of this has been the war in Ukraine, where drones were deployed by Ukrainian troops to great effect against Russian troops. Small, fast, and cheap, drones are a very viable military solution. Moreover, in critical locations like airports and monuments, where drones are not permitted to fly, they are a safety risk and general nuisance.

Cost efficient, effective solutions are being sought to identify and remove unwanted drones. What are effective methods to take down such small and fast targets? In the Netherlands, Dutch Police have started working with Raptor training companies to attempt to train birds to hunt down drones [2] More conventional methods include simply using firearms or using other drones carrying nets [3]. These methods all have their flaws, however. It takes time and money to train birds, and drones can be very difficult to hit using conventional firearms. Nets have their own limit, as other anti-drone technology like jamming [3] might be effective against them.

To remedy this, we wish to investigate a system for identifying and tracking drones in space. These drones can then be safely removed or have protective actions in place to safeguard individuals. To do so, we will need to design the system that uses a variety of technologies to identify exclusively drones and their locations in space for a wide variety of environments.

1.2. Areas of Application:

As drones are becoming more common, they become more of a concern to airfields [1], historic sites [4], and other areas where they risk people's safety or cause general disturbances. As such, having a system that safely identifies and eliminates drones from entering these areas will preserve the safety and enjoyment of the public. A system like this would likely have uses by airports, cities – for use in drone safe parks, areas of extreme natural beauty, conservations, and away from high density residential areas – along with other forms of government sites for historic preservations, and finally for amusement parks, sports stadiums, and entertainment venues [1] where excessive drone use could cause harm to attendees and disrupt the event taking place. Overall, this system could be used in situations where public safety, or public privacy are in jeopardy, and where drones will distract from a service, cause damage, or infringe on a paid service. These applications omit military defence, where drones are being shown to be a major avenue for attack and proper identification leads to effective defence.

1.3. Technical Advancement:

Modern environments are dominated by the latest and greatest tech, and these technologies are not always used with the best of intentions. Defending against new technologies requires constant development and iteration as older devices can not keep up with new technology. Many methods used to intercept drone technologies are manually operated, leaving the operator to be the deciding factor. By automating the drone takedown process, many of the uncertainties lie in the software and hardware used, removing the human factor. Designing a device to handle the new features of today's drone technologies will require a thorough understanding of the latest and greatest in drone technologies.

Civilian operated drones in restricted airspace are simple enough to disband or eliminate. The difficult aspects of drone interception are found in the militarized aspect of drone use. Fiber-optic drones have become very popular [5] and are impervious to jamming technology, leaving the only option to be physical disposal. Drone swarms [1] can overwhelm manually operated defense systems, leaving them vulnerable.

1.4. Key Developments:

Drones are rapidly advancing in both capability and accessibility, raising significant security and safety concerns. Malicious actors exploit drones for hostile uses including suicide drones built to crash into a designed target, drones equipped with weapons and guns or drones carrying explosives.

Moreover, drones are also becoming smaller, camouflage with their environment and are becoming undetectable by radar [5] or other detection system, making them hard to localize and disable. In addition, the declining cost and widespread availability of drones has made these technologies easily accessible to the public, which in turn raises critical privacy, security, and surveillance concerns.

A great concern to many people is that autonomous weapon could malfunction and harm innocent bystanders. Obviously, this will need to be taken well into consideration, and any risks to unintended targets will need to be mitigated.

2. REQUIRMENT SPECIFICATIONS

2.1. Marketing Requirements

The marketability of the solution rides on several factors, including topics discussed in Section 5.3. The essential aspects of which involve:

- Marketable to the individual and to large companies based on needs [6]
    - Provides a solution that large companies can incorporate into their existing infrastructure
    - Individual users can implement the solution without overly burdensome installation
- Delivers solution to present problems [1]
    - Modern
    - Limited susceptibility to technological advancements
- Manufactured at scale
    - Scalable
    - Possibly modular
    - Ubiquitous components

2.2. Engineering Requirements

The engineering requirements will dictate the general minimum functionality we expect the solution to have. The solution must facilitate the following:

2.2.1. Movement

- Have a full range of motion in a semi-spherical domain
    - Sees everything above itself to maintain line-of-sight
    - Improvements on this range would be vey useful
- Have a feedback mechanism to determine its orientation
    - To track the drone and relay reliable data, the relative position must be known
    - Allows potential for additional equipment to target the drone

2.2.2. Acquisition

- Must be able to track a specific object defined by detection mechanism [7]
  - Repeated identification of drone location is essential
  - Even misidentified objects should be tracked until they are determined to be safe
- Must have feedback system to determine if the target is locked into "sights", or if further movement is necessary
  - Continuously updating to ensure exact position

2.2.3. Algorithm

- Requires software that allows it to operate autonomously
  - Removing human error from targeting system
  - Human authorization still required before any installed intervention mechanism
- Image processing for detection of movement [7]
  - Camera (visible light, IR or otherwise) will capture drone movement
- Data processing to calculate distance of target
  - To determine the distance to the object in 3-D
  - Reliably track movement in all directions

2.2.4. Detection

- Defines different objects in its field of view
  - All moving objects must be identified
- Classify small flying objects in field of view [7]
  - Distinguish drones, passenger aircraft, birds, etc.
  - Essential for safety and reduced environmental impact

2.3. Constraints

There are certainly constraints on several aspects of this system, many of which involve legal restrictions. The list legal domains and regulatory bodies that the solutions must conform to is extensive. These constraints are:

2.3.1. Legal

- Airspace regulations

  - Compliant with Transport Canada, Federal Aviation Administration (FAA), European Union Aviation Safety Agency (EASA) or other regulatory bodies in applicable country
  - Uses zoning and restrictions from NAV Canada, FAA or other regulatory body
  - International Civil Aviation Organization (UN) regulations observed
- Radiofrequency (RF) regulations
  - Licensed spectrum from Radio Advisory Board of Canada (RABC), The International Telecommunication Union (ITU), or other regulatory body
  - Certification and Engineering Bureau (CEB) compliant hardware
  - Any regulatory bodies in other countries
- Electrical code
  - The device will need a power source from the grid
    - Compliant with Canadian Electrical Code (CEC) or electrical code in other countries
- Intellectual property
  - Existing technologies such as [7] cannot be copied
  - Our system must provide new, improved aspects to drone detection
- Licensing
  - Any aspects that are required from other IP must be licensed
  - License to operate in airspace and RF domains are required

2.3.2. Safety & Environmental

- Must not aim at humans or wildlife
  - Important aspect of object identification
  - Birds appear very similar to drones
- Reliable kill switch
  - Hard-coded and physical switch
  - Prevents runaway autonomy
- Safe for commercial planes
  - Commercial planes can also appear as drones
  - Reliable distinction between manned and unmanned aircraft
- Fire safety measures
  - Precautions in case of electrical fire hazards
- Human verification before intervention
  - To ensure a final check on the autonomy, human verification is necessary

2.4. Criteria

In order to measurably confirm that the solution conforms to the requirements within a reasonable margin, a list of criteria must be met as follows:

2.4.1. Functionality

- Field of view
  - The field of view encompasses the region of space that the device can monitor
  - Must encompass a reasonable domain
- Detection accuracy
  - Accuracy is a common metric for object detection

$$\text{Accuracy} = \frac{\text{True Positives} + \text{True Negatives}}{\text{Total Predictions}}$$

- False detection rate
  - Common metric as in [8] is F1 which includes false positives and false negatives:

$$\text{Precision} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Positives}}, \qquad \text{Recall} = \frac{\text{True Negatives}}{\text{True Negatives} + \text{False Negatives}}$$

$$\text{F1} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

  - More informative than accuracy alone
- Time to target
  - The time required for the device to lock onto the drone after it is detected
- Power consumption
  - Power consumption must be reasonable
  - Minimal burden on private consumer power bill

2.4.2. Complexity

- Ease of use
  - Can be used by both untrained civilians and military
- Cost
  - The cost must remain very competitive while maintaining the outline performance metrics
- Reliability (malfunctions)
  - The device must function well without catastrophic failures

2.4.3. Durability

- Weatherproof
- Maintenance and repairs

3. SYSTEM FEATURES AND SPECIFICATIONS

We propose to design and build a detection system for drones to identify and subsequently lock-on to said drones. This system would utilise a large sweeping detection scheme, and once a drone is detected, would switch a higher precision detection system that has a smaller field of view, is more precise, and is servo actuated. This secondary detection system would "lock-on" on to the drone, using servo actuation to follow the motion of the drone through predictive software utilising AI and powerful image processing techniques.

3.1. Software Components

3.1.1. Detection Software

- Voxel movement method
    - To detect small object movement, the Voxel movement method detects changes between frames and highlights them
    - This software will provide an image source for deep learning methods to capture
- Radar detection
    - Software will be created to use radar detection
    - Will determine the general location of any movement
    - Allows camera to rotate to area and examine further

3.1.2. Identification Software

- Advanced-Areial-Drone-Detection-System Repository [9]
    - Repository used to base drone detection software on
    - Can be altered to integrate with new application
- YOLOv8
    - AI deep learning model commonly used for drone detection
    - Comparable version referenced in [10]
- OpenCV
    - A large library of open-source computer vision (CV) and machine learning application software
    - Used in [9] to facilitate deep learning

3.1.3. Positioning Software

- Pan-Tilt HAT python library
  - Used to control the pan-tilt HAT
- RPi-Pan-Tilt-Servo-Control Repository [11]
  - Specialized repository allowing servo motor control in a pan-tilt mechanism

3.2. Hardware Components

3.2.1. Logic Controller

- Raspberry Pi
  - Suitable platform for high-processing power
  - Allows software to communicate with hardware effectively
  - Runs python code required by the voxel method and deep leaning model
- Servo-motor HAT
  - To control the servo motors effectively, a HAT (hardware attached on top) will be installed
  - Improves the communication between the Raspberry Pi and the motors
- Image Detection HAT
  - To improve the processing speed of the cameras, an image detection HAT will be used

3.2.2. Detection System

- Camera
  - The main detection methods will be implemented using image processing software
  - In order for the Voxel method described in 3.2.1 and the deep learning model in 3.2.2 to operate, there must be at least one available image stream
  - Multiple cameras could be implemented to improve speed, accuracy and field of view
- Radar system
  - A basic radar system is used to initially locate any moving objects without expensive image processing

3.2.3. Movement Mechanism

- Pan-tilt Mechanism
  - To maintain the full 180° by 360° field of view needed, a pan-tilt mechanism suits the domain perfectly
- Servomotors
  - To operate this pan-tilt mechanism, the axes will be powered by servo motors
  - These will be operated by a HAT on the Raspberry Pi

Using these hardware and software components, we will design a system that meets a cohort of specifications. These specifications outline the performance of the system and ensure that the final design meets the desired solution specifications. These specifications are as follows:

3.3. Design Specifications

3.3.1. Functionality

- Field of view
  - 360° panoramic field of view
  - 180° tilt field of view
- Detection efficiency
  - The accuracy rate at which the drones are detected must exceed 80%

$$\text{Accuracy} = \frac{\text{True Positives} + \text{True Negatives}}{\text{Total Predictions}} > 80\%$$

  - Sufficient to meet detection rates in [8] by similar methods
- False detection rate

$$\text{F1} = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} > 75\%$$

  - This metric must exceed 75% to meet values in [8]
- Time to target
  - Time between detection and system lock on the drone must be within 2 seconds
  - This will allow a drone travelling at a high rate of speed, 75 kmph, across a radius of 20 m to be identified
- Power consumption

    - Based on the security camera in [12] which requires PoE class 6 power, 20W to 60W
    - The system may require additional power for movement
    - To keep the device practical for all users, it should consume less power than a 100W lightbulb

3.3.2. Complexity

- Ease of use
    - Device must be operable by untrained user with a manual
    - Simple commands such as "start" and "stop" buttons
- Required parts
    - Parts must be accessible and replaceable for everyday users
        - Microcontrollers like ARM, Raspberry Pi or Arduino
        - Standard motor sizes such as NEMA frame size
    - Ubiquitous components
        - Capacitor, inductor and resistor values follow specific E-series
        - Maintain standard for any connectors between boards or components such as 2.54mm spacing between pins on headers
- Cost
    - Many similar products from ~$400 [13] to hundreds of thousands for large systems such as the vendors in [7]
    - To be competitive, the device must cost less than the lowest priced vendor by a significant margin because if it's limited capabilities
    - The criteria for the price will be set at a sale price of $300
- Reliability (malfunctions)
    - All parts must be replaceable
    - Data on one device must be transferrable in the event of repair or maintenance

3.3.3. Durability

- Weatherproof
    - Withstands major temperature swings
        - -30°C to 50°C
    - Handles rain and snow
        - Waterproof
        - Identifies drones in snowy conditions
- Maintenance
    - Parts are accessible
        - No glueing or other form of permanent adhesion
        - Can be easily disassembled with screwdriver, latches or other hardware

    - Configuration is easy to comprehend
        - No complicated bunches of wire
        - Simple, logical flow
- Time to repair
    - Cannot be shut down for long periods
        - Regular maintenance takes less than an hour

Using the components listed, the device will be constructed to satisfy the defined specifications, which fit the desired solution to the problem. The design will use a Raspberry Pi programmed with radar and Voxel-AI integrated software will use the pan-tilt mounted camera and radar to locate and target airborne drones.

4. PRODUCT DESIGN

The design concept for our product is a camera system capable of moving hemi-spherically (over the surface of a hemisphere) and when it detects a drone, to center it in the camera's field of view and track it. The main sources of input are then position of the camera, and the video feed from the camera to make decisions as to whether objects are drones. We intend to use 2 detection methods in tandem to improve detection accuracy and perform the detection with cheaper lower resolution cameras. The first being the Voxel movement method to simply detect any moving objects, then a deep learning mode to filter objects as drones. Using these 2 methods the system will be able to operate in 2 different modes, an idle scanning mode where it is looking for a drone, and a tracking mode for when a drone has been identified. How this works can be seen in Figure 1, where each mode takes the position and feed as inputs, communicate to each other which mode the system is in, and output a correction to the camera position.

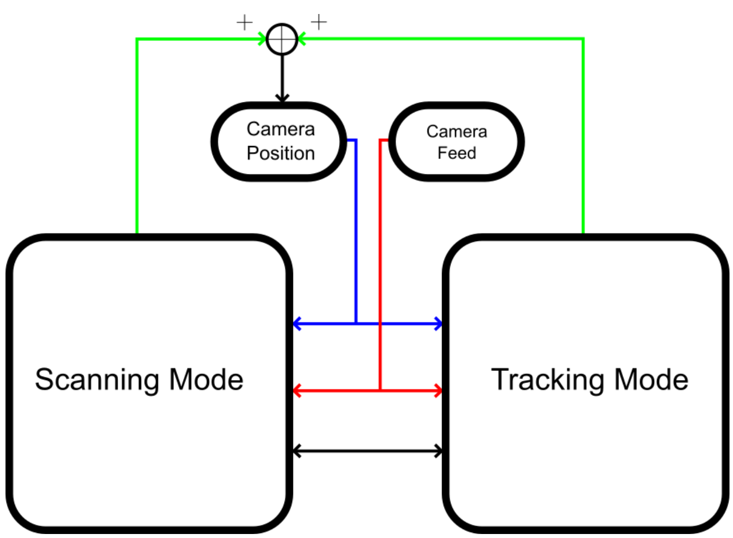

Figure 1: General Block Diagram

The operation of the scanning mode is outlined in Figure 2. Within the scanning mode the current camera feed and position are subtracted by previous values of position and feed. Simultaneously, the previous values are updated with the current values. This subtraction serves as a comparison if anything moved, and the magnitude of movement. The comparison then moves through a threshold filter to remove subtle movement from the moving camera and the environment. The output is the current feed image and a truth table of where movement is detected (if any). On its own this forms the basis of the Voxel method. The next step it to analyze the image where movement is detected for if the objects were drones using the deep learning. The output here is a Boolean value $S(t)$ stating if a drone was detected or not and the image $I(t)$. If no drones were detected the mode outputs the next position in the scan. If a drone is detected $S(t)$ and $I(t)$ are passed to tracking mode (Figure 3).

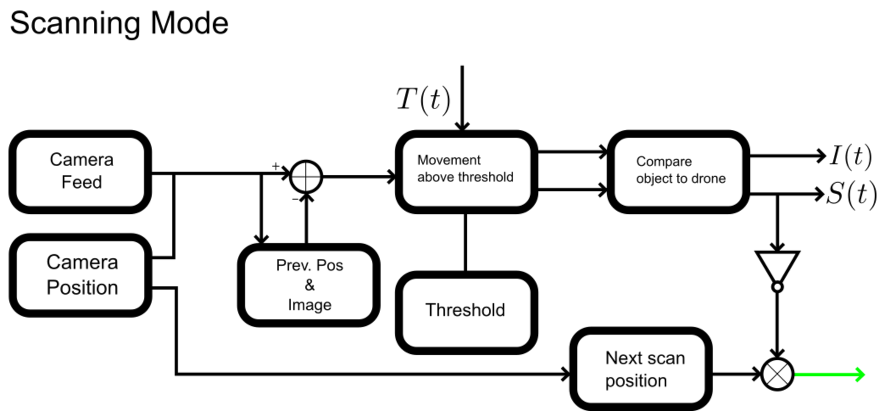

Figure 2: Scanning Mode Block Diagram

In tracking mode $I(t)$ is used as an initial image to determine the position of the drone in frame, where it is then subtracted by the current center of frame. This difference tells the system how much and where to move, for the drone to be centered in frame. At the same time, more images are collected to determine the position of the drone and fed back into the system following the drone. At each step, the detection output another Boolean $T(t)$ pausing the detection in scanning mode (Figure 2) while there is an active drone being tracked.

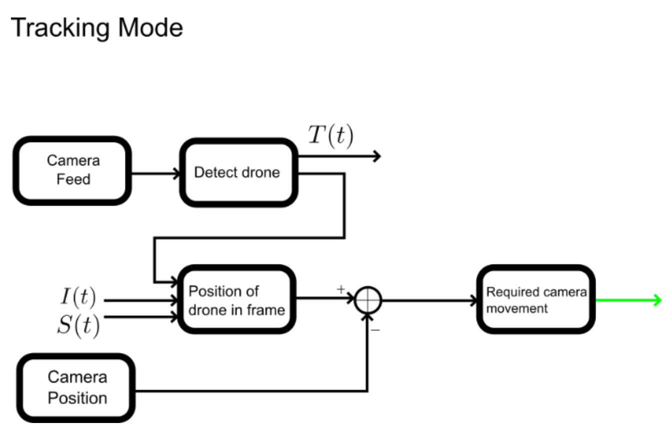

Figure 3: Tracking Mode Block Diagram

4.1. Simulations

To test whether this design will work we simulated the detection schemes, both the Voxel method and the deep learning model. The purpose of this simulation is to whether our intended detection scheme would work, the limit to the accuracy of detection, and the level of processing involved. For both models we started with a stationary camera to test if detection is possible without camera motion effecting the results.

4.1.1. Deep Learning Model

In the deep learning model, the YOLOv8 Deep Learning Model was trained recognize drones using images libraries from Roboflow. The trained model identified drones in the still image seen in Figure 4. The confidence intervals in this image provide an optimistic projection of what a better trained model could achieve in terms of the accuracy and F1 requirements laid out in 3.3.1.

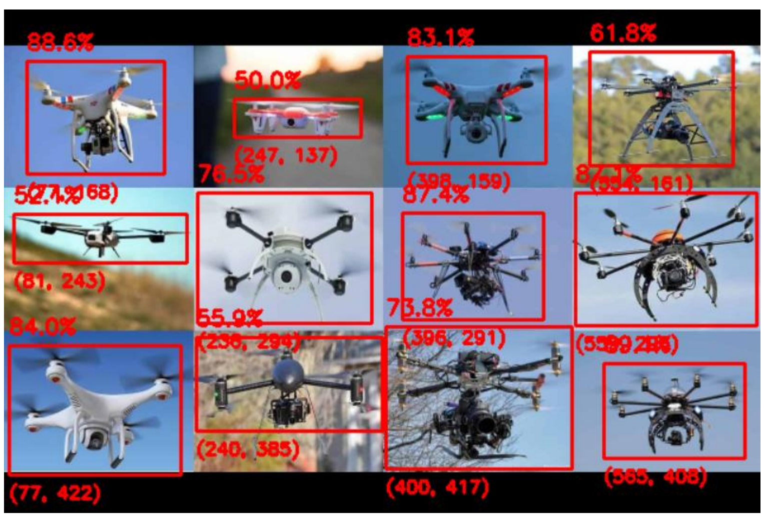

Figure 4: YOLOv8 Trained Model Drone Identification with Confidence Intervals

The trained model was successful in identifying and tracking images of drone during a live camera feed as seen in Figure 5. However, the deep learning software had significantly reduced confidence intervals when the image became lower in resolution.

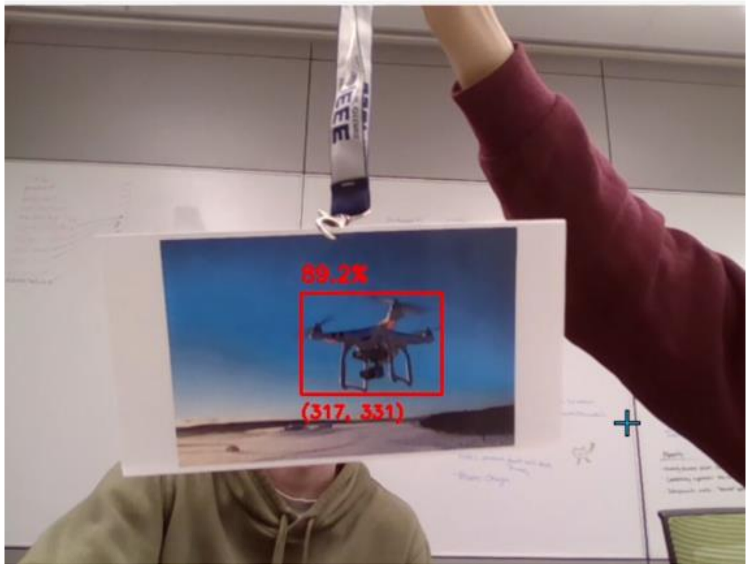

Figure 5: Deep Learning Model Drone Recognition

Overall, this test does indicate that when presented with an image any drones can be identified and isolated in frame. The test was also able to output the location in frame of the drone for the tracking application, so that the system can move to keep the drone in frame.

4.1.2. Voxel Movement Method

With the voxel method we had a computer take video input and compare subsequent frames clean the output and produce a heat map of movement. For a still camera this was very effective at detecting small, fast-moving objects (Figure 6), and larger, slower moving object closer in frame. As a stand-alone test, this demonstrates that this method was very effective at filtering out only moving objects, that can eventually be passed to the deep learning model for further processing and filtered the majority of the environment.

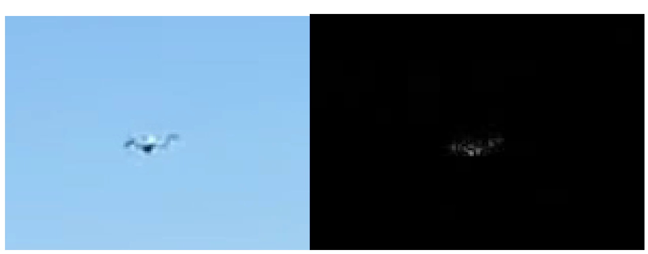

Figure 6: Voxel Movement Detection

4.1.3. Comparison to Design Specifications

As part of our design specifications in under 3.3.1 we want to detect a drone moving at 75 km/h at 20 m from our system. Then set the requirement for a stationary camera that the system requires a minimum of 4 frames to perform the movement detection, identify the drone with deep learning and begin tracking, we can find the minimum frame rate for processing. If we also assume a camera with a narrow field of view (FOV) of 75° we have the case in Figure 7. The angular velocity of the drone ω is 1 rad/s, and the FOV is 1.3 rad.

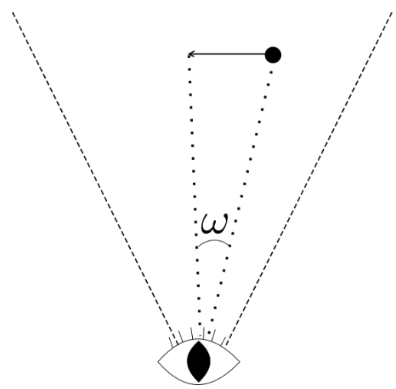

Figure 7: Minimum Frame Rate Diagram

The frame rate (R) can then be solved as

$$\#\ of\ frames \times \frac{\omega}{FOV} = R.$$

For our conditions we get a value of 3 frames per second (fps). Both simulations were capable of processing 10 fps at a relatively high resolution of 1080p in real time. Meaning the simulations' processing time for a single frame was less than or equal to the time between frames at 10 fps. These results are very encouraging as it means in the ideal case the simulations perform at above minimum, leaving some buffer when moving to the physical system.

4.2. Deliverables

The final solution must achieve tangible results that can be measured and compared to the system specifications. These results will demonstrate the functionality of our solution and define what separates it from similar works. These distinctions provide valid intellectual property that provide the foundation for our viability and marketability. To ensure we have the appropriate results we define the deliverable components of the solution as follows:

- The accuracy of drone identification
  - Previously defined in section 2.4.1
  - Provides precise, comparable metric to other detection methods
  - The confidence interval of our model will also provide a general idea of accuracy
- F1 metric
  - Defined in section 2.4.1
  - Includes the failure rate of the detection method
  - More informative than the accuracy

The resulting final product would include both the physical camera mounting system, and the final detection and tracking software. Where the software would form the basis of our unique IP in the final deliverable.

4.3. Testing Procedure

Our method of drone detection differs from the detection methods laid out in [8] as it involves distinguishing movement between frames. Many of the tests conducted in [8] involve simple tests using still imagery and Monte-Carlo simulations. To comparably test our device, we will test over short segments of video in random order to provide comparable Monte-Carlo simulation of drone images. The recommended tests for our final system are the following:

- Combined Monte-Carlo (combined detection of both the Voxel and deep learning)
  - Short segments of video with, and without drones are fed into the combined detection scheme
  - Detection output and confidence is compared to actual drone locations
  - Final accuracy is determined
  - This test is performed with both a moving and stationary camera
- Camera motion
  - Final mounting system is tested for range of motion

        - The system is actuated to full range of motion to test if it meets design specifications
    - Specific position test
        - The mounting system is given a specific final position given an arbitrary start
        - Using internal sensors and a pointer see if system orients to desired position
- Full system test
    - With full system implementation move images of drones and other objects into camera view
    - Using indicator light to indicate when the system is in tracking mode
    - Attach a pointer to camera mount to point to objects being tracked for accuracy measurement
    - Moving object in and out of frame record the number of true detections and false detections
    - With correct detections record the accuracy of the pointer
        - how well it follows (does it lag behind or stay locked on)
        - how close to the image (does it keep the pointer centered on the image, what error)

5. BUISNESS MODEL

In order to transform our project into a business, a list of possible partners, resources, customers, and revenue streams is needed to plan how it will operate and succeed. One method of organizing these aspects is using a business canvas, like the one below. The purpose is to organize how the business will operate, what is needed to survive, who it will work with and their relation, finally summarizing costs and revenue streams.

Key Partners

Grant Holders
- Government of Canada
- Department of National Defence

Parent Investors
- Thales
- Dedrone
- D-fend

Key Activities
- Product manufacture
- Product/material storage
- R&D
- Legal
- Sales/marketing
- Consulting

Key Resources
- Manufacturing and Assembly Facilities
- RF and laser licensing
- Testing space
- Training data and software tools

Value Propositions
- Detection and tracking Software
- Detection and tracking apparatus (physical sensor system)
- Low usage cost
- Autonomous platform

Customer Relationships
- Market to companies, governments, agencies
- Maintain customers through representatives
- Consulting
- Training and repair

Channels
- Contract biding
- Consultations
- Expos
- Google search results
- Pilot programs
- Business to business marketing

Customer Segments
- Militaries
- Personal Landowners (anti-surveillance)
- Airports
- Entertainment venues
- Correctional Facilities
- Power plants and key infrastructure

Cost Structures
- Value-Driven

Fixed Costs
- Product R&D
- Patent filing
- Licencing
- Facility cost (storage and manufacture)

Variable Costs
- Product manufacture
- Product installation/shipping
- Maintenance
- Shares / trading

Revenue Streams
- Government grants
- Product Sales
- Investment
- Patent licensing
- European defence fund
- Upgrade option
- Consulting
- Shares / trading

5.1. Key Partners

Key partners look into additional partners who would support the business and their motivation for doing so. As an example, one strong potential partner is the Government of Canada more specifically the Department of National Defense. The government is willing to provide grants for the continued development of anti-drone designs . Here the government can fund designs that they can then use for national defense with minimal commitment of resources. Regardless, the ability to access grants for continued research and development, and operation makes them a key partner. Then there are companies such as Dedrone, Thales, and D-fend who are current companies in the anti-drone space. These companies would initially be competition but serve as potential investors to branch out into new markets. For Dedrone being a mainly American company investing serves as a way to branch out into the Canadian market, Thales primarily focuses on military radar for drone detection and may wish to enter the civilian market, and D-fend focuses on jamming technology and may be interested in acquiring actual detection and tracking abilities.

5.2. Key Activities

Key activities looks into the essential actions required to implement and sustain the business model. These activities ensure that the organization delivers its value proposition, maintains operations and builds long term partnerships. For example, Product manufacture, Research and Development (R&D) which keep improving the product to meet market need and align with government standards, driving more innovations.

5.3. Key Resources

The main question this section tackles is: what are the necessary resources to operate? As we intend to develop a physical system a manufacturing and assembly facility is required to build the products. Then for the development of additional products and technologies we will likely require several unique licenses such as radio frequency (RF) licenses and laser licenses. But to actually test the results of any R&D we will require testing space and training data, along with appropriate software tools and safety measures.

5.4. Value Proposition

The value of any product is governed by its demand and its competition. In this case, the demand for anti-drone technology is steadily increasing as the number of reported drone incidents increases year over year [14]. There is already a growing market to quell this demand, but sectors such as national defense are constantly evolving to keep up with new technology. Our proposed solution aims to provide an innovative autonomous defence system capable of drone detection and removal without constant monitoring. The solution also removes the effects of human error and provides a versatile platform to target unwanted drones with any type of deterrent or munition. Our software, hardware and intellectual property will be valuable to other companies that aim to create similar products. This leaves several avenues for potential value in our product besides the device itself.

5.5. Customer Relations

Our primary focus is interacting with potential customers from a sales perspective; however, there are additional ways of interacting with customers for retention and acquiring new ones. One of the key ways is by continuing to have customer representatives to offer support and repairs as needed, and providing consultations on designing, implementing, or upgrading systems with customer needs.

5.6. Channels

In order to have customers there must be a way to reach customers, this is what we consider channels. For the service we are providing, typical consumer channels, like running TV ads, wouldn't reach our target customers. As such, the best ways to reach potential customers are more targeted like contract biding, attending and demonstrating at expos, Google search results, and consultations for customers already interested in the market. However, to reach new customers pilot programs, and business to business marketing are ways of convincing them that we can provide a quality product and service.

5.7. Customer Segment

Identify the specific group of people or organization that will benefit from our product and potentially become customers/clients. For example, government organization such as the department of National Defense which could be using our anti drone mount for national security and surveillance. Another segment would be law enforcement agencies and public safety departments which would use our system to protect high-risk areas such as bank, nuclear station, airports.

5.8. Cost Structure

Our cost structure is centered around a value-driven product, aiming to create a comprehensive solution to the problem posed rather than a simple solution that can be mass produced. Many of our potential customers are focused on good-quality products and could have potentially large budgets for our type of technology. The breakdown of our costs can be divided into two main categories: fixed cost, the costs that will always be required to complete; and the design and variable costs, the costs that grow as we begin to increase the production of the devices.

The fixed costs must include basic costs incurred by any startup including research and development, company facilities, and any licensing or government regulation overhead. These are to be expected but will remain constant throughout the product lifetime.

The variable costs are the costs that are incurred as the size of the company and production levels increase. These costs include manufacturing, storage, maintenance, and if the company becomes public, any investment share payouts.

5.9. Revenue Streams

To survive as a company there must be a way of making money to fund standard operations, and growth. Evaluating possible sources of revenue for a company is what defines Revenue Streams. As mentioned earlier a possible partner is the Government of Canada by providing grant funding for certain types of anti-drone designs [6]. Considering that the Canadian government is providing grants along with other sources like the European Defence Fund are sources of revenue specifically for continued R&D related activities. The remaining sources stem from traditional sales, consultations, and licensing of our products and Ips; along with investments and the sale of shares.

6. DIVISION OF RESPONSIBILITY

The product will, overall, have two main subsystems: the detection subsystem (through voxel movement and image processing) and the actuation subsystem.

The detection subsystem will be handled by Duncan and Isaac. So far as the current simulations show, the methods can track drones in videos without requiring a long processing time. The next steps to implement this subsystem include bridging the gap between live video recording through cameras, and real-time processing and tracking. A detailed plan for completing this step will be ready by February, including basic code and protocols related to the implementation. Following this is implementing the code into a Raspberry Pi. This will depend on how fast the BOM gets approved, and how efficiently an SBC can be acquired.

The actuation subsystem will be handled by Leo and Christopher. This subsystem will use two coupled motors to create the hemi-spherical motion required. The first step to implementing this subsystem will be to design with CAD a model of the required components. A first prototype will be 3D-printed as proof of concept, and any further adjustments made will be based on findings from the design phase and prototyping phase. To note, a crucial decoupling mechanism will be needed to protect the wires and electronics from torsion due to the 360-degree rotation of the base plate. The chosen physical design will depend on the decoupling design chosen. Moreover, this subsystem will require code to command the position of the servos based on spherical coordinates from the detection subsystem.

Certain dependencies exist, limiting how much the team can work in parallel. For example, the tracking algorithm that moves the camera cannot be properly tested until the actuation system is built and functional. As such, the schedule will require both subsystems proceed at a comparable rate.

7. PROJECT SCHEDULE

The Key milestones for the next 4 months of this project are as follows:

- Present preliminary design ideas for implementation: early-mid January
- Present findings to the group with full design (full BOM, CAD, Code packages): early-mid February
- Purchase of materials and components: mid-February
- Prototyping phase of the actuation subsystem: late February
- Implementation and testing of the code on to the Raspberry Pi: late February
- Full systems test and debugging: early-mid March
- Final product ready: mid-late March

8. BUDGET

Our project is designed to be a proof-of-concept prototype, so the budget is focused on the vital components cost of our project rather than large scale manufacturing. The main cost drivers are the Processing and sensing, actuation hardware and other miscellaneous parts

- **Processing and Sensing (~ 140 -200 CAD)**
  A Raspberry Pi with a compatible camera module are required to run the drone-detection and tracking algorithms in real time, acquire images and command the servos to move accordingly

- **Actuation Hardware (~ 70 - 100 CAD)**
  Two high-torque servos motor and a mount are needed to mechanically steer the mount in both axis over the specified 360° x 120° field of view

- **Power and Safety (~ 30 – 40 CAD)**
  Power regulator, DC-DC buck converter and an emergency kill-switch or stop button to ensure safe operation and compliance with the safety constraints

- **Miscellaneous electronics and components (~ 30 – 40 CAD)**

  This includes wiring, connectors, screws, nuts, electric tape, jumper wires and other miscellaneous components

9. QUALIFICATIONS

Duncan McRae

Physics and Electrical Engineering Student

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613-330-3436
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EDUCATION

Honours BSc Physics and BASc Electrical Engineering

University of Ottawa / Ottawa, ON. / 2021 – Present

- CGPA 7.7 / 10
- Deans Honours list 2022, 2023

SKILLS

Computer Skills: SOLIDWORKS, Multisim, Microsoft Office

Coding languages: Python, C, MATLAB, HTML, CSS, VBA, Assembly.

Personal skills: teamwork and collaboration, problem-solving, verbal communication, and written communication.

Technical skills: circuit analysis, equipment maintenance and repair, machinery operation, metalworking, carpentry, welding, soldering, manual labour.

EXPERIENCE

BluMetric Environmental Inc. CO-OP / Carp, ON. / Jan. – Aug. 2025

- Disassembled and assembled water filtration units.
- Created documentation for assembly of various water filtration units.

Farm Hand / Charlottengro Farms Inc. / Williamstown, ON. / 2020 – 2023

- Operated, maintained, and repaired equipment.
- Installed new equipment when necessary.
- Completed tasks on time and under rapidly changing conditions.

Construction Labourer / Dave Lawson Woodworking Ltd. / Jasper, AB. / Sept. – Dec. 2020

- Operated construction equipment and power tools.
- Learned and applied construction techniques including reinforced concrete, foundation work, framing, insulation, and roofing.

Farm Hand / Heidi Farms Inc. / Bainsville, ON. / 2016 – 2023

- Performed multiple roles in milking operations during early and late hours.
- Operated equipment during harvest season.

PROJECTS

Engineers Without Borders / Jan. - Mar. 2023

- Worked with fellow engineering students to design new systems for Mazi Ltd. in Kenya using SOLIDWORKS.

First Year Engineering Design Project / Sept. – Dec. 2021

- Designed and programmed applications for Zafin using various programming languages and platforms.

Second Year Engineering Design Project / Jan. – Apr. 2022

- Worked with team of engineering students to design accessibility part for the Tetra Society of North America.

Leo Dionne

leo.laurent.dionne@gmail.com | ldion089@uottawa.ca | (438) 764-1062

Languages Spoken: English | Francais

Education

Physics and Electrical Engineering, BSc and BASc, University of Ottawa

Specialisation in Electronics | Expected Graduation Year: 2027

Experience

Research Assistant, National Research Council of Canada

January 2025 to Present

- Conducted research on electromagnetic non-destructive evaluation methods analytically using MATLAB and python.
- Experimentally verified theoretical analysis by measuring the impedance of a planar eddy current coil through a lock-in amplifier.
- Utilised a Hall sensor to observe the magnetic field distortions created by the introduction of a notch into an Al plate with a planar eddy current coil.
- Develop MATLAB scripts to complete image processing without access to any toolboxes.

Electrical Sub-Team Junior Lead, Kelpie Robotics, University of Ottawa

September 2023 to Present

- Utilised KiCAD and later Altium to design schematics to fulfil different needs on the main team robot. Led a small team to design PCBs for power regulation and motor control.
- Designed major components of the team's vertical profiling float, a small autonomous device designed to collect underwater data. Designed 3D-printed housings and mounts for motors and electronics to fit inside a small cylindrical space. Designed the schematics for the electronics, which included identifying the exact sensors used, the power source, and the fuses required.
- Tested individual circuitry systems using multimeter and oscilloscope.
- Produced Bill of Materials and coordinated with others to create a design that complied with a 247 x 147 x 86 mm space constraint.
- Represented Kelpie Robotics at University of Ottawa open house events.

Skills

Programming	Software
MATLAB and Simulink	KiCAD
Python	Altium PCB
C	Onshape
Arduino	Office Package
	TecView UT

Christopher Wong

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BUSINESS MANAGEMENT & ANALYSIS

Driven Fourth-year Physics and Electrical Engineering student with a focus on Renewable Energy, seeking roles that leverage technical expertise and analytical skills in sustainable energy systems, circuit design, and data analysis. Fluent in English, French, and Mauritian Creole, with strong proficiencies in software development, experimental analysis, and leadership.

KEY COMPETENCIES

- Proficient in Python, C++, MATLAB, Multisim, PCB Design, and CAD
- Circuit Design & Semiconductor Physics
- Technical Analysis & Experimental Monitoring
- Strong Report Writing and Presentation Skills
- Electronic Systems & Solar Energy Applications
- TO ADD

PROFESSIONAL EXPERIENCE

Physics Science Mentor | Sept 2023 – Present
University of Ottawa
• Organized and hosted weekly study groups to assist students in understanding and tackling concepts covered in PHY1321 and PHY 1322, fostering collaborative learning environments conducive to academic success
• Assisted students in developing effective study plans, providing guidance on time management and exam preparation strategies
• Scheduled and conducted student meetings to address their concerns, fostering a supportive and mentorship environment
• Involved in mentor training sessions to acquire the necessary skills and resources to promote engagement and academic success

Lab Tour Guide | Sept 2023 – Present
University of Ottawa
• Oriented tours for new students and parents, showcasing the Biology, Chemistry, and Physics Laboratories
• Hosted custom and interactive onboarding workshops, addressing key differences and providing insights for a smoother transition
• Responded to general inquiries related to university life, academics, fostering a welcoming and informative environment for visitors

Canada Post Agent May 2023– August 2023
Jean Coutu Pharmacy, Ottawa, Ontario
• Efficiently processed parcels into the system, accurately recording weight, size, and addresses
• Facilitated money transfers through MoneyGram and Money orders, ensuring secure financial transactions
• Conducted daily inventory checks to maintain stock levels and ensure the availability of essential products
• Mastered cash register processes to ensure accurate closing and balancing on closing shifts, averaging a variance of less than 1%

EXTRACURRICULAR ACTIVITIES

- **Design of Broadband Antireflection Coatings for Solar Cells**
Optimized antireflection coatings for solar cells using MATLAB/Python simulations, enhancing power transmission through the Transfer Matrix Method (TMM)
- **Sun Tracking Solar Panel**
Built a dual-axis solar tracker with Arduino for optimized solar energy capture, enhancing efficiency by dynamically adjusting panel angles based on sunlight direction.
- **Supermileage Uottawa**
Member of UO Supermileage, the University of Ottawa's premier electric vehicle team, I contributed to designing and building energy-efficient vehicles for international competitions

EDUCATION & CERTIFICATIONS

- **CEED badges**
Certified for various tools and equipments such as 3D-Printer, Latte, milling, Laser Cutter, Welding, Arduino and basic tools and machinery
- **Certified Mentor, ROTARACT and SCOUT**
- **Certified Delf B2**
- **First Aid Certified**

REFERENCES

Victoria Obeid	Audrée Moynan
Senior Coordinator	Student Support and Mentor
University of Ottawa	University of Ottawa
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vobeid@uOttawa.ca	audree.moynan@uottawa.ca

Isaac Soward

Qualifications

- 5th year Physics and Electrical Engineering CO-OP at University of Ottawa
- Excellent with teamwork and communication through work experience
- Problem solving and analytical skills from working in a laboratory setting
- Very comfortable working with programing environments for Python, and MatLab
- Fluent in English and adept with French

Education

Bachelor of Science, Honours in Physics (CO – OP) September 2021 – Present

University of Ottawa (Ottawa, ON)

Bachelor of Applied Science, Electrical Engineering (CO – OP) September 2021 – Present

University of Ottawa (Ottawa, ON)

Relevant Skills

Laboratory

- Trained in Laser safety
- Conducted Experiments using Free Space Optics
- Conducted research related to Single Photon detectors, and photodetector characterization

Engineering

- Wrote code for analyzing lab data, and autonomous operations
- Strong understanding of engineering design methods

Technical

- Main programing languages: Python, MatLab
- Knowledge of analytical techniques such as curve fitting, covariance analysis, data averaging

Communication

- Gave regular project updates at group meetings
- Familiar with technical report writing
- Regular large team communication in on-the-job settings

Relevant Work Experience

Undergraduate Research Assistant, (January 2025 to August 2025)
TRIUMF, Science Technology Division, Single Photon Detector R&D , Vancouver, Canada

- Wrote numerical simulation code in Python
- Designed experiments using simulation results
- Performed data analysis, and statistics in Python

10. CONCLUSION AND FUTURE ENDEAVOURS

Ultimately, this design promises to be achievable within the deadlines provided and provide a reliable way to detect airborne unauthorised drones. The device will use a custom software system incorporating the Voxel movement method, and deep learning implemented on a Raspberry Pi 5. Currently, both methods have been simulated with promising results. Under ideal conditions both methods were able to provide reasonable detection of moving objects and isolating drones in images. A minimum camera frame rate was determined for a drone operating at our design specification limits to be detected, and both methods were able to process videos at a higher rate with high resolution images. With proper integration and optimization this processing rate should exceed design minimums.

Over the course of the next four months, our team will focus on issues related to practical implementation: optimising the code for use on a Raspberry Pi 5 and assembling a system to allow for hemispherical motion. As well as, integrating the 2 detection schemes together.

The hemispherical motion system will require a lengthy process of trial and error after an intense design phase. Key considerations include mechanical decoupling, servo capacity, and physical size. Mechanical decoupling will be based on independent motion-permitting joints to allow the servos to properly orient the camera, without twisting wires and risking breaking them. The servos will be selected based on their torque, price point, and size. A size-torque ratio will be considered, based on minimum torque required for the movement. Together, these considerations will allow for a reliable device to be created that can meet all design specifications.

To conclude, the subsystems will come together to create a device that can be used to mount a more powerful defensive system to remove drones. With the specifications and requirements in mind, it will be possible to create a device that can complete this task accurately and efficiently.

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