Autonomous Drone for Search and Rescue

Grant Proposal

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Executive Summary

Search and rescues are crucial and require hastened action, but they are very time consuming. In this document, we propose the engineering of an autonomous drone that can expedite the search and rescue process. This drone will be capable of human detection using a custom-trained YOLO model. The data will then be stored and reported to a human supervisor.

Autonomous Drone for Search and Rescue

Search and rescue

Search and rescue missions are crucial in safeguarding human lives during emergencies and natural disasters. These missions often require a substantial investment of resources, including financial funding, fuel, and the dedicated involvement of human rescuers. The complexities in these operations, along with the need for rapid responses, have placed immense strain on organizations involved in search and rescue efforts (Waharte & Trigoni, 2010).

The financial costs associated with search and rescue missions are significant, with maintenance of equipment, compensation for rescue teams, and the logistics required for mission coordination. Moreover, the heavy reliance on fuel for conventional search and rescue vehicles, such as helicopters and boats, contributes to a considerable environmental footprint. Human resources are also a main component of search and rescue operations, with skilled personnel risking their safety to aid those in need. In addition, human rescuers' safety is always a safety concern, particularly in disaster-stricken areas. Using Unmanned Aerial Vehicles are often seen as solution to search and rescue missions.

Unmanned Aerial Vehicles (UAVs)

Unmanned Aerial Vehicles (UAVs) are pilotless aerial vehicles. They are small, reliable, and do not require advanced equipment and measures to take off and land. In addition to that, they can perform more intelligent tasks. Over the past few years, there have been many advances in tasks performed by UAVs. UAVs have been used to perform various tasks, such as environmental monitoring, wildlife population tracking, wildfire monitoring, and border patrol (Erdos et al., 2013).

Using Autonomous UAVs for Search and Rescue

Since UAVs are versatile, they could be deployed in a wide range of SAR scenarios. Unlike conventional search and rescue teams, which may require significant time and resources, UAVs can be launched swiftly. The swiftness of UAVs are especially useful in time-sensitive situations, where every minute counts in potentially saving lives (Półka et al., 2017).

Traditional SAR operations often necessitate substantial financial investments in equipment, fuel, and personnel. However, UAVs drastically reduce these costs. Furthermore, they minimize the risk to human lives by performing tasks in hard-to-reach areas, ultimately reducing the reliance on human resources (Naidoo et al., 2011).

Drones also excel in navigating challenging terrains, such as areas affected by natural disasters, rough landscapes, or remote regions. They can fly at various altitudes, making them ideal for conducting aerial surveys over large, inaccessible areas.

Moreover, the autonomous technology integrated into UAVs enables them to autonomously scan vast areas and identify survivors. Advanced image recognition software can detect human figures and share their exact locations with SAR teams. This capability expedites the rescue process, eliminating the time-consuming and labor-intensive task of manually searching for survivors.

However, to perform the search and rescue tasks, the drone must be capable of planning its own math and detecting humans using image recognition.

Path planning

One of the key aspects of path planning for drones involves the implementation of search patterns. Search patterns are predefined routes drones follow to systematically cover an area and search for specific objects or information. These patterns are particularly essential in applications like search and rescue missions, where time is of the essence, and thorough coverage of an area is crucial. Here are some commonly used search patterns:

Expanding Square Search

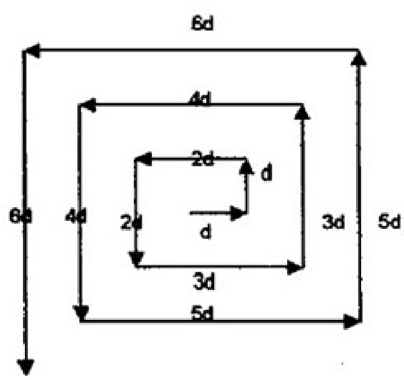

Figure 1: Expanding square search pattern (New Zealand)

An expanding square search is a method used to locate a lost object or person over a wide area. It involves creating a series of squares that get larger with each iteration. The search begins at the estimated location of the object or person and expands outward until it covers the desired area. One advantage of this method is its systematic coverage, ensuring no part of the designated area is overlooked. However, a potential drawback is the time and resources required, as the search area expands exponentially with each iteration, making it more time-consuming for larger areas (IAMSAR Manual).

Parallel Track Search

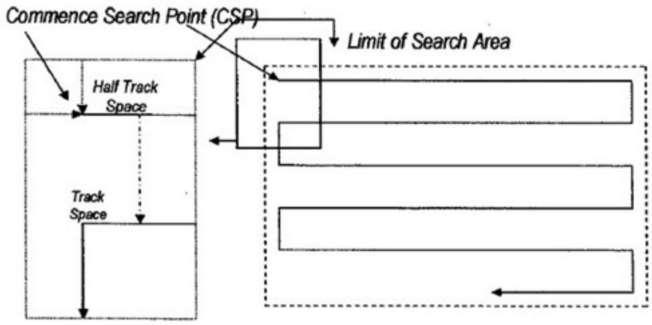

Figure 2 Parallel track search pattern (New Zealand)

A parallel track search is a search pattern used to cover a large area of water systematically. It involves creating a series of parallel lines spaced at a distance equal to the expected visibility of the target. The search begins at a known point and proceeds along the tracks until the entire area has been covered. One benefit of this approach is its efficiency in covering vast expanses of water. Nonetheless, a challenge may arise if the visibility of the target is inconsistent, potentially leading to areas being overlooked due to the predetermined spacing of parallel tracks (Jiang et al., 2022).

Sector Search

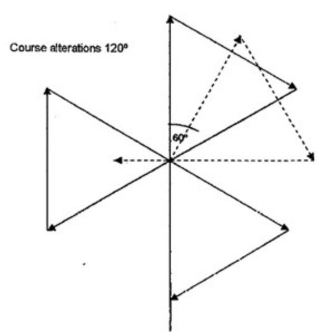

Figure 3: Sector Search (New Zealand)

A sector search is a search pattern used to cover a specific area of water known to contain a lost object or person. It involves creating a series of radiating legs that start at a central point and extend outward like the spokes of a wheel. The search begins at the center and proceeds along the legs until the entire sector has been covered. An advantage of this method is its targeted focus on known areas of interest. However, a limitation may be the possibility of missing objects or persons located outside the predetermined sectors (*New Zealand)*.

Creeping Line Search

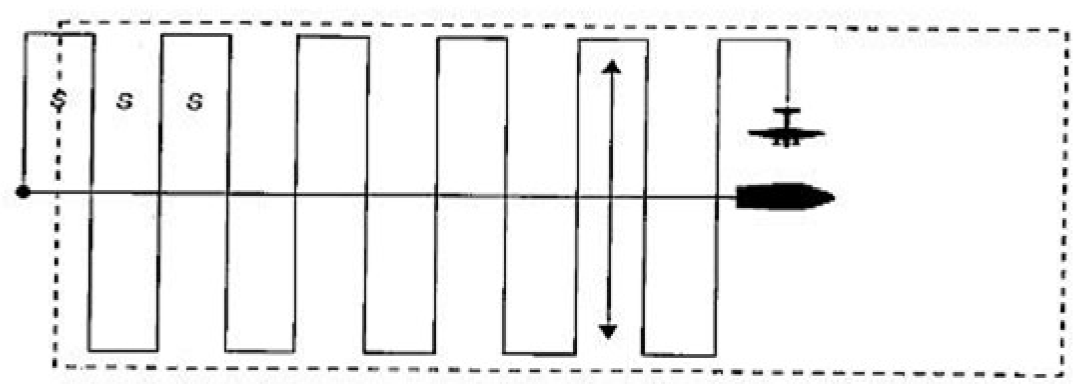

Figure 4: Creeping line search pattern(New Zealand)

A creeping line search is a search pattern used to cover a long, narrow area of water, such as a coastline or shipping lane. It involves creating a series of parallel tracks spaced at a distance equal to the expected visibility of the target. The search begins at one end of the area and proceeds along the tracks until the entire area has been covered. The benefit of this method lies in its suitability for covering extended, narrow regions. On the downside, it may be less effective in wider areas, as the parallel tracks might not provide comprehensive coverage, potentially leaving gaps in the search (Arnold et al., 2018).

Human Detection Algorithm

Human detection and tracking are tasks of computer vision systems for locating and following people in video imagery. Human detection is the task of locating all instances of human beings present in an image, and it has been most widely accomplished by searching all locations in the image (Davis et al., 2009). The most implemented methods are Frame Differencing,

Circular Hough Transform and, Histogram of Oriented Gradient-based methods (Raghavachari et al., 2015).

Overall Goal

The primary objective of this project is to engineer an algorithm that equips drones with the capacity to independently perform search tasks. This autonomy will enable drones to scan vast areas, identify potential survivors, and share critical information with human rescue teams rapidly and systematically. By reducing the time and resources required for search and rescue missions, this drone would improve overall mission efficiency.

Section II: Specific Aims

Our overarching objective is to simplify search and rescue efforts by eliminating the reliance on human resources, reducing time-consuming processes, and optimizing resource expenditure through the utilization of an autonomous drone system. The central hypothesis driving this proposal is that advanced drone technology equipped with human detection capabilities will serve as a transformative solution for enhancing sea rescue missions.

The rationale behind this approach comes from the understanding that autonomous drones, with their capabilities and advanced sensors, can outperform traditional methods, ultimately leading to quicker and more reliable responses in critical situations. By harnessing this technology, we aim to enhance search and rescue missions.

The work we propose here will involve a multi-part development process, with each part contributing to the enhancement of drone technology. The drone will be capable of identifying an appropriate search path, detecting humans, and reporting its results back to a human supervisor.

Specific Aim 1: Identify an effective search pattern to determine the path traveled by the drone.

Upon successful completion of this aim, the drone will possess the capability to determine an optimal search path. The drone can autonomously navigate through different maritime environments, adapting its trajectory to cover large search areas. The autonomous navigation will lead to a reduction in time-consuming processes associated with manual path planning.

Specific Aim 2: Identify humans and stranded vessels.

This aim will result in an autonomous drone equipped with advanced detection algorithms capable of accurately identifying humans and stranded vessels leading to a quicker response time, ultimately increasing the chances of successful rescues.

Specific Aim 3: Store and report the results of the detection algorithm.

With the successful implementation of this aim, the autonomous drone will not only identify and locate humans and vessels but also communicate this critical information back to a human supervisor.

The completion of these specific aims will result in an autonomous drone system that could revolutionize sea rescue missions. The expected outcome is a technology that significantly reduces human reliance, expedites response times, and optimizes resource management.

Section III: Project Goals and Methodology

Significance

This project's significance lies in its potential to revolutionize sea rescue efforts by deploying autonomous drones with human detection capabilities. By minimizing response times and reducing reliance on human resources, the technology aims to better search and rescue operations, particularly in maritime conditions. The project's focus on efficient search patterns, coupled with the ability to detect individuals and stranded vessels, enhances overall effectiveness, increases safety for rescue personnel, and ultimately saves lives in critical maritime emergencies.

Methodology

1. Multiple search patterns will be simulated to cover a specified region. The most efficient search pattern will be chosen by the drone.
2. A custom image detection model will be developed to detect human and vessel presence.
3. Results of the image detection model will be stored on an onboard SD card along with a timestamp, current location, and detected images in that location.

Specific Aim #1: Identify an effective search pattern to determine the path traveled by the drone.

The objective of this specific aim is to identify the most effective search pattern for the drone to follow. We intend to achieve this specific aim using a Python Turtle simulation. A Python Turtle is a geometric model that can simulate various real-life models (Formiconi et al., 2022). The above-mentioned search patterns will be coded in Python using the Python turtle class. The turtle will be considered a drone. Hence, by simulating the movement of the turtle, we simulate the movement of the drone.

Simultaneously, we will simulate the random movement of a victim in the grid. We will randomly pick a point on the grid and then measure the time it takes for the drone (the turtle) to come within a 20-unit radius of the randomly chosen point. Once measured, we will then simulate the scenario of a random walk. A random walk is a random process that describes a path including, a succession of random steps in the mathematical space (Xia et al., 2020). We will once again measure the time it takes for the turtle to come within a 20-unit radius of the "random walking" victim. We will then conduct a 2-sample t-test to determine if there is a difference between the chosen search pattern and their detection time in the stationary victim case and the moving victim case.

Justification and Feasibility

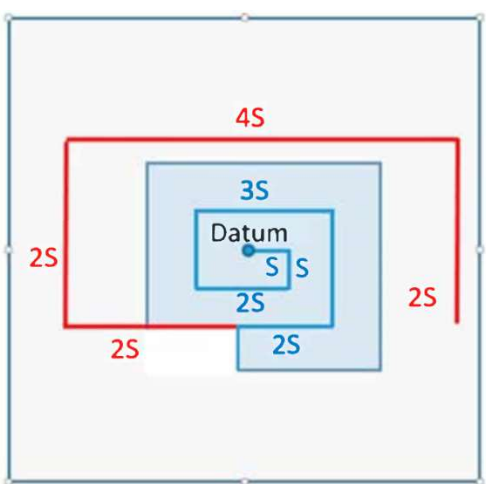

Figure 5: Probability distribution of people found in SAR missions using the Expanding square search pattern(Burciu et al., 2020)

Choosing an effective search pattern with low time consumption will allow us to calculate probability distributions of the presence of the victims in certain regions. By determining these distributions we can answer the question "What part of the search region are victims more likely to be found?". This question was answered for the expanding square search pattern in "The Impact of the Improved Search Object Detection on the SAR Action Success

Probability in Maritime Transport" by Burciu et al. (2020). In this paper, it was found to be that most victims were found in the inner half of the expanding square. We could get valuable insight about the distribution of people found in a given area if we approach this simulation using the proposed methodology. By finding the least time-consuming search pattern, we can analyze what makes the search pattern so efficient, where we would consider the probability distribution of the presence of the victim.

Expected Outcomes

The overall outcome of this aim is to experimentally find the most effective search pattern. The most effective search pattern will then be used to build probability distribution maps for the presence of victims as well as be used as the path traveled by the drone autonomously.

Potential Pitfalls and Alternative Strategies

We expect some null cases where the random walk of the victim can go outside the initially planned search area by the drone. While this could easily be addressed in the simulation, we are yet to find a solution or an alternate strategy for this in the real-world case.

Specific Aim #2: Identify humans and stranded vessels.

The objective of this aim is to equip the drone with human detection capabilities so it can autonomously identify humans and stranded vessels during its search process. We intend to achieve this using a modified YOLO method. The YOLO stands for "You Only Look Once". It is a convolutional neural network that predicts he bounding boxes and class probabilities for all the objects depicted in an image (Diwan et al., 2023). There are 8 versions of YOLO, YOLOv1 through YOLOv8. YOLOv1 is the base model. It uses a single neural network to simultaneously predict multiple objects in the same image (Du, 2018). In this project, we will use this model as it requires smaller datasets to train and is capable of detecting multiple objects in a single frame.

Justification and Feasibility

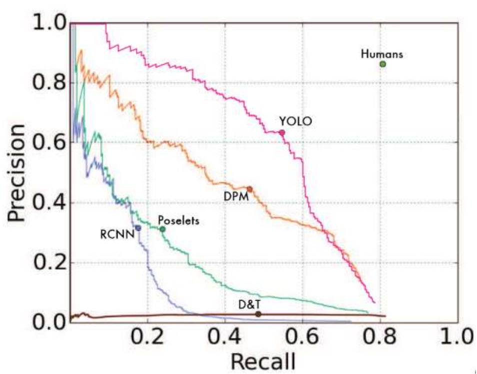

Figure 6: Precision vs recall graph comparing YOLO and other commonly used object detection models (Redmon et al., 2016).

This model will enable us to detect both humans and vessels in the sea. Modifications will be made to this model so that it is immune to distraction such as fish, or any other marine animal. In addition to that, it is more accurate compared to other commonly used object detection models (Redmon et al., 2016)(see Fig.6). Using this model will improve computation time and simultaneously provide high detection accuracy.

Expected Outcomes

The expected outcome of this specific aim is an object detection model with a highly accurate real time object detection. This will then be installed on a raspberry pi computer on to the drone.

Potential Pitfalls and Alternative Strategies

One possible pitfall is the lack of appropriate datasets. This model must be trained on UAV images for the best results. However, such databases are hard to find, especially for maritime environments. An alternate strategy to this is to train the model on UAV images of land. While this would not be as accurate as a model trained on UAV images of the sea, this would be a viable alternative option.

Specific Aim #3: Store and report the results of the detection algorithm.

The objective of this aim is to ensure that the drone can effectively communicate its results back to a base station or a human supervisor. To do this, we will use a Raspberry Pi SD card logger. We will then log a current timestamp, the current location as coordinates, and an image of the surroundings if the YOLO model detects anything above a set confidence level.

Justification and Feasibility

Logging this data will be extremely helpful to human rescuers who then have to go find exactly where the lost person at sea is. Logging the time and an image of the surrounding environment makes sure that the human rescuers have all the data they need to be better prepared for search and rescue.

Expected Outcomes

With the successful implementation of this logging technique, the drone will have a perception of its own accuracy. For example, if it detects a human with a confidence of 0.5, it can check again in the same place to see if it can detect a human again with better confidence.

Potential Pitfalls and Alternative Strategies

Potential pitfalls of this strategy include the ignorance of false negatives. It is not possible for the drone to log false negatives unless the drone saves every frame of video, which is not ideal because it increases power and energy consumption.

Section IV: Resources/Equipment

- Computer
- Drone simulation software
- Drone
- Camera

Section V: Ethical Considerations

One ethical concern to be addressed is the presence of human subject's faces on the testing images. To address this, we will blur out their faces when showcasing our results.

Section VI: Timeline

Present-December 12: Preliminary testing using python Turtle.

December 12-December 26: Preliminary build of the YOLO model.

January 1- January 15: Real simulation of both YOLO and the drone's path planning combined.

January 15-January 30: Build the physical drone.

January 30- February 10: Real world testing of the drone

Section VIII: References

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