Machine Learning Project Proposal WGU C951 Task 2 Nicholas Hartman #001035619 08/16/21

Project Overview

This proposal is for a software development plan to add machine learning to our fire detection drones.

Organizational Need

Currently, we have to have a person out on the field plan the path for every drone released into the area of suspected fires. This takes time and can delay the deployment of the drones. Also, because the person may not know the specific terrain layout, this can lead to crashes and the loss of drones. A machine learning path planning algorithm would help reduce the time to deployment because the drones wouldn't need initial human intervention to start detection but also, with the machine learning algorithm, the drones would be able to detect and avoid obstacles, reducing the loss of drones due to crashes in the field.

Context and Background

As fires become larger and more prevalent, it is becoming harder to monitor in finer detail areas where fire is spreading and is increasing danger to human workforces.

Interval	Fires	Acres
5-Year Average (same interval)	4874	574564
2021 Combined YTD (CALFIRE & US Forest Service)	6511	1072225
2020 Combined YTD (CALFIRE & US Forest Service)	5963	838197

(CAL FIRE)

This increase in fires will require innovative ways to detect and monitor the fires while simultaneously reducing the size of the workforce required and decrease time to alert.

Outside Works Review

Outside Work 1

A Probabilistic Target Search Algorithm Based on Hierarchical Collaboration for Improving Rapidity of Drones

Finding a target quickly is one of the most important tasks in drone operations. In particular, rapid target detection is a critical issue for tasks such as finding rescue victims during the golden period, environmental monitoring, locating military facilities, ...

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6111375/

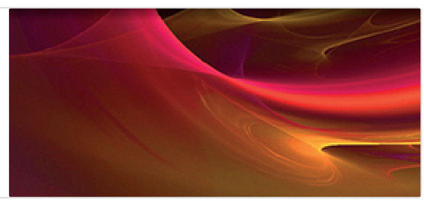
This first article outlines how to use drones at various altitudes to narrow down search areas. A single drone at high altitude can break the search area up into quadrants in which is then generates a probability that each quadrant contains fire or not. Time reduction is obtained because a drone at a higher altitude can benefit from being able to search a wider field faster. As the drone's height is increased the search area can be increased by widening the sensor field. The higher altitude also eliminates worrying about finer terrain details like trees and other obstacles that could impact drones at lower altitudes. It is demonstrated that methods utilizing hierarchical searches with drones are comparatively excellent and that the proposed algorithm is approximately 13% more effective than a previous method and much better compared to other scenarios(Ha).

Outside Work 2

A New Dynamic Path Planning Approach for Unmanned Aerial Vehicles

Dynamic path planning is one of the key procedures for unmanned aerial vehicles (UAV) to successfully fulfill the diversified missions. In this paper, we propose a new algorithm for path planning based on ant colony optimization (ACO) and artificial potential field.

https://www.hindawi.com/journals/complexity/2018/8420294/



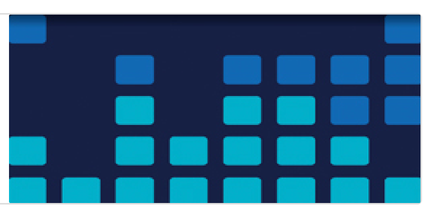
This article outlines dynamic and global path planning algorithms to navigate a drone through terrain with both predetermined (global) and unknown obstacles (dynamic). Drones released at higher levels could gather data about potential obstacles, which is then used to create the global environment map. The drones at lower levels or the drones that are predicted to need more fine-grained path planning can use the method laid out in this article. This article outlines the use of the Ant Colony Optimization Algorithm. As outlined by the article, the underlying idea is that a starting point and a target are determined. Then a set of waypoints are generated dynamically to get from the start to the target point. The waypoints are then traversed using static and dynamic obstacle detection. Each drone that travels the waypoints successfully increases the success of the path. This is transmitted to other drones, utilizing the same path to get to the target. This will eliminate the need for human intervention in the initial release phase of the drones. Where previously we had to have a human plan out each path for each drone, we can now utilize multiple drones and just input the starting point based on the initial release point of the drones and target points based on the drones reporting from high altitude.

Outside Work 3

Online Path Generation and Navigation for Swarms of UAVs

With the growing popularity of unmanned aerial vehicles (UAVs) for consumer applications, the number of accidents involving UAVs is also increasing rapidly. Therefore, motion safety of UAVs has become a prime concern for UAV operators.

https://www.hindawi.com/journals/sp/2020/8530763/



This article outlines how multiple drones can be used to plan routes and avoid collisions. The article outlines three different collision types and their avoidance. Those three types are:

- UAV to UAV collisions
- UAV to static obstacle collisions
- UAV to moving obstacle collisions

It does this by using complex event processing (CEP) is a technique for real-time, fast processing of a large number of events from one or more event streams to derive and identify important complex events and patterns in the event streams(Ashraf, A.). This will allow the automatic control of large groups of drones in the field, which is integral to the fast deployment and quick-fire detection of our proposed solution.

Solution Summary

Our organization has to utilize a workforce in determining both potential fire location and individual drone path planning. With work 1, we can dramatically reduce the time needed to find potential fire locations through drones at higher altitudes. High altitude drones can be released and search a wider area faster and report back the predicted locations of fires, which can be used to create the target points for the lower altitude drones. Work two and three can be utilized in the drones at lower altitudes to navigate the terrain, find the fire, and track the fire front as it moves through the environment. Work two takes the starting point, which is wherever the human element can safely reach to start the deployment of the drones and the target point generated from the high altitude drones to generate a path dynamically through the environment. Work three can be used in tandem with work two to ensure real-time updating of the generated path through the environment. In short, our solution is to utilize the three works describe above to generate a complete solution to fire detection and monitoring.

Machine Learning Benefits

All of the described works, working together, can increase the time to detection of fires, reduce danger to the human element, and provide continuous monitoring and safety of areas impacted by frequent fires.

Machine Learning Project Design

Scope

In Scope

- Drone acquisition and hardware/sensor planning: The type of drone and sensors required will be planned for and implemented.
- Drone software for fire locating: software for locating the fire will be developed and installed on the planned drones utilizing hardware/sensors acquired.
- Drone software for on going fire monitoring: software for monitoring the fire will be developed and installed on the planned drones utilizing hardware/sensors acquired.

Out of Scope

- Fire containment: Drones will not be outfitted with anything to help contain the fire or prevent is spreading.
- Fire suppression: Drones will not be outfitted with anything to put out the fire or reduce the fire in any given area.

Goals, Objectives, and Deliverables

Goals

The goal is to provide a fleet of drones that can be utilized to locate and monitor fires in terrain that is dangerous or inaccessible to humans.

Objectives

- Acquire proper drone types to fill out fleet of drones.
- Acquire proper hardware/sensor types to outfit drones equip drones for proper fire detection
- Develop machine learning software for high altitude drone fire locating
- Develop machine learning software for low altitude drone path planing, obstacle avoidance, and fire detecting.
- Package drones and software together to create a turnkey solution for fire detection and monitoring

Deliverables

The deliverables will include a fleet of drones preloaded with software for the detection and monitoring of fires.

Standard Methodology

The CRISP-DM method will be used for the project.

Business understanding:

- Each attempt to locate an environment with a fire can be considered its own business operation. Requirements from this perspective will include defining the area of search which can be mapped to converting the area into the data mining problem. First we would need to pick a safe location to drop off the human drone deployers. Then setup the area of search as the data mining area. The high altitude drones can be part of the preliminary plan to help achieve the fire locating objective.

Data understanding:

- The initial data collection phase will take place with the high altitude drones. These drones will collect data with GPS, proximity sensors for obstacle detection, and an infrared sensor to detect changes in temperature. The lower altitude drones once deployed will gather data from their GPS, proximity, and infrared sensors that will be transmitted back to the base station.

Data preparation:

- A cleaned data set will be transmitted back to the base by the high altitude drones. This data set can have a layout similar to <DRONE NAME>(X: {gps.x}, Y: {gps.y}, Z: {gps.z}). This cleaned data set with clear parsable markers can be used to update the lower altitude drones to the location of the fire. The lower altitude drones will gather the same data as the higher altitude drones but in more of a real time manner. They will gather, clean and transmit while in flight. This will be used for terrain and obstacle avoidance. This data will also be used to update the base station so mapping of the environment can be saved. The final data set will include GPS data for all drones, proximity sensor data for all drones, and infrared sensor data for all drones.

Modeling:

- After the data is collected by all the drones, and then prepared the data can then be added into a simulated 3D model of the area. This 3D model can be updated in real time by the drones to create a visualization of the movement of the fire.

Evaluation:

- This 3D model will be evaluated by people back at the base station. At this point any anomalous data can be either discarded from the 3D model or malfunctioning drones can be called back to the base station if required.

Deployment:

- Once the 3D model has been created and evaluated it can be upload or streamed to local emergency personnel or to a website for alerting local residents to the potential fire encroaching on their property.

Projected Timeline

Name	Assign	Date	Property	Status
Proposal acceptance		@August 11, 2021 → August 14, 2021		
Technical Proof of Concept		@August 15, 2021 → August 31, 2021	Coppelia Sim Model of working drones	
Proof of Concept accepted		@September 1, 2021		
Drone hardware acquired		@September 2, 2021 → September 6, 2021	Chip shortage may delay	
Drones assembled		@September 7, 2021 → September 11, 2021		
Software developed		@September 12, 2021 → September 30, 2021		
Drone and software test		@October 1, 2021 → October 5, 2021		
Drone hardware tested		@September 12, 2021 → September 30, 2021		
Drones with software delivered		@October 6, 2021 → October 10, 2021		

Sprint Schedule

Name	Assign	Date	Status	Task
Sprint 1		@September 12, 2021 → September 15, 2021		Software for High altitude drones created
Sprint 2		@September 16, 2021 → September 19, 2021		Software for low altitude drones created
Sprint 3		@September 20, 2021 → September 24, 2021		Base station software for data gathering and 3D modeling
Sprint 4		@September 25, 2021 → September 30, 2021		Software for coordinating drones created

Resources and Costs

Resource	Description	Quantity	Individual Cost	Total Cost

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Drone	drone to add sensor and software package too	25	$1,000.00	$25,000.00
Sensor Package	sensor package including all required sensors. GPS, Proximity, and Infrared	25	$500.00	$12,500.00

Evaluation Criteria

Objective	Success Criteria
Time to deployment reduction	A 50% reduction from onsite to full deployment of drones.
Drone loss reduction	A 75% reduction in drone loss due to collisions
Accuracy of drone fire tracking increase	A 25% increase in fire tracking accuracy

Machine Learning Solution Design

Hypothesis

The problem is creating a faster more robust method of drone flight planning and path creation. This will help our organization save money and reduce potential human loss in fire impacted areas.

Selected Algorithm

The primary algorithm used for the generation of the drone flight path will be the Ant Colony Optimization Algorithm

Algorithm Justification

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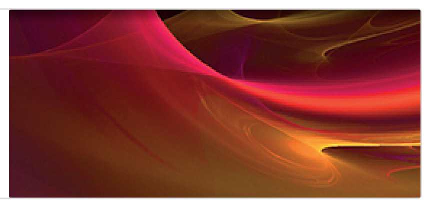

This algorithm will be advantageous to solving our organizational need because it allows path generation using a starting point and an end target point. The starting point will represent the deployment location and the target point will represent the predicted location of the fire. Once the starting point and target point are determined the drones can be released and will be able to generate their own paths without human intervention.

Algorithm Advantage

This algorithm has the advantage of already having the ability to navigate and handle multiple drones built into it. Each drone can work off the data provided by another drone that has already navigated the area. This could lead to optimal path finding for each subsequent drone.

Algorithm Limitation

One limitation is that to work effectively this algorithm has to be paired with another algorithm. The Artificial Potential Field Algorithm works in conjunction with the Ant Colony Algorithm to allow for obstacle avoidance. Using two algorithms that need to feed into each other could lead to undesirable conditions in a multithreaded environment. If one algorithm is running and needs the other algorithm as support, knowing how best, and at what times to interrupt the two algorithms could be tricky and lead to weird drone behavior.

Tools and Environment

Coppelia Sim will be a good place to start. This tool can be used to model algorithmic activity in a simulated environment. Once development gets fully underway a language like c or c++ would be desirable. These language's memory management and optimizable foot print lend themselves better to embed environments that will be required on the drones. A linux desktop environment with gnu c compiler and an IDE of developers choice should be more than adequate for algorithm development.

Performance Measurement

Performance will be measured by how well the algorithm can handle realtime environment data from multiple data sources. If the algorithm can handle the data in realtime then that will be sufficient for the project. Quality will be measured by number of collisions handled and avoided. Deployments with were less than 10% of drones crash will be considered optimal for first release.

Description of Data Sets

Data Source

The data will be extracted from the sensor package built on to the drone. This package will pull GPS, proximity, and infrared data from the surrounding environment.

Data Collection Method

Data is collected from the sensor package. It is then cleaned and tagged and transmitted to a local base station. The base station converts cleaned and tagged data for reading into a 3D environment modeling software package. This displays a 3D model of the fire in relation to the surrounding area for monitoring and alerting.

Data Collection Advantage

Through the use of the drones data can be collected fast and with out injury to human workers.

Data Collection Limitation

Data collection is limited to the quantity of drones deployed. More drones can map an area to finer detail but will add cost and complexity to the project.

Quality and Completeness of Data

For the completeness of the data. The data will be streamed in realtime from drone to base station. This will allow for quick drone navigation with regards to terrain and other drone avoidance. As for the quality, data will be tagged in a way that is quickly parsable by the other drones and the base station using a tagging system.

```
<DroneName>(X:{gps.x}, Y:{gps.y}, Z{gps.z})
```

A tagging system that looks like this can be modified to add more attributes quickly and should be relatively efficient to transmit over wireless data.

Precautions for Sensitive Data

Sensitive data can be managed at the 3D modeling software level. If the drones are being utilized on private property or an area were privacy is expected, the alerting and internet uploading features of the 3D modeling software can be turned off.

References

- Ashraf, A., Majd, A., & Troubitsyna, E. (2020, January 11). Online path generation and navigation for swarms of uavs. Scientific Programming. https://www.hindawi.com/journals/sp/2020/8530763/.
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- Huang, C., Lan, Y., Liu, Y., Zhou, W., Pei, H., Yang, L., Cheng, Y., Hao, Y., & Peng, Y. (2018, November 5). A new dynamic path planning approach for unmanned aerial vehicles. Complexity. https://www.hindawi.com/journals/complexity/2018/8420294/.