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EENG 4640 – EE/CpE Capstone Senior Project

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Project Summary

The purpose of this project is to research, design, and fabricate an autonomous drone that will aid firefighters when there is an emergency. The use of drones or other UAVs have been on the rise and this technology could be used to help against an issue that is always prevalent. This project will create a drone that will be able to seek out fires and possible fire hazards that can help alleviate the amount of volunteers that would be put at risk. The drone uses a combination of different sensors in order to simulate a flight controller, an accelerometer, gyrometer, barometer, and distance sensors. Currently firefighters are at considerable risk whether it is physical or mental stress and pain. Firefighters are exposed to burns, smoke inhalation, and are at risk to falling debris. Issues from fighting fires can also bleed to the home-life in the form of heart disease, lung damage and cancer.

With the added help of drones we will be able to reduce the risk that people are placed into while fighting off infernos. Drones are becoming more and more common through surveillance, observation and different types of applications. Drones will be able to reduce the amount of human error while assessing a situation and reduce the response time needed to solve the problem. Drones will also allow the user to focus on other imperative tasks that might require a human's concentration and more immediate thinking by anyone in the area.

As we research the project and complete the project we will find the best solution to create a safe and affordable autonomous drone. Fires are a constant threat to civilization and in recent years the amount of fires that have occured has increased. There are 358,300 home based fires on average per year and there were 499,000 structure fires for the year of 2017. This type of tragedy causes the death of civilians every two hours resulting in 2,620 deaths a year. When wildfires are taken into account there were 1,291,000 fires in the U.S which resulted in 16,600 injuries and 3,704 deaths for the year of 2019. Fires also contributed to $14.8 billion lost in 2019. With the sheer amount of people that are affected by fires along with global warming on the rise, the risk of fires becoming more prevalent, being able to use drone technology to help combat this issue would be an ideal situation.

Literature Review

Introduction

The aim of this literature review is to identify and explore previous projects that have previously implemented the use of Unmanned Aerial Vehicles for fire fighting. This review investigates the capabilities of using Unmanned Aerial Vehicles to rapidly address the complex problem of rapidly increasing fires. Furthermore, this project seeks to pair the Unmanned Aerial Vehicles with a video streaming camera and artificial intelligence to help automate the fire detection process. The implementation of artificial intelligence, and more specifically Computer Vision, will allow for faster fire detection rates as well as to provide automation. In order to have a well rounded understanding of how to approach this problem.

Related Works

The first feature this literature review is focusing on is the use of Unmanned Aerial Vehicles for fire fighting and extinguishing. The implementation of the UAVs comme switch several perks to the field. For example, the risk of human lives to combat fire can be drastically reduced due to remote control of the UAV itself. As discussed in [3], the UAVs are implemented around the perimeter of the fire. Since the fire has an undetermined flight path, this paper explores the use of infrared sensors to collect images of regions below the drone. The infrared images are then used to command the drone and follow the path of the fire. Some of the most important aspects this paper touches upon is the communication range of the UAVs. It is primordial to have proper connectivity with the drone to maintain flight control. In the case of the project developed in this proposal, an RFID scanner will be used for the drone to return to home base once a certain limit of connectivity has been reached. Furthermore, the team will implement a Pixie camera and a thermo sensor to detect the fire and the path it has taken. The team is also exploring computer vision techniques such as Convolutional Neural Networks to detect fire through the Pixie camera and allow for UAV automation.

[4] is another paper that explores the use of Convolutional Neural Networks and UAVs for natural disaster assessment. This research leverages the use of a Matrice 300 RTK as their primary drone to conduct assessments of natural disaster-damaged roads. The research focuses

mainly on classifying among six different types of damages on roads. However, the scope of this paper can be expanded to include fire hazard detection. With respect to this paper, this proposal seeks to enhance and build upon their results. One key improvement the team seeks to achieve is to conduct real-time fire detection (classification) in contrast to sending the video feed to ground-station and classifying after the fact. With real-time fire detection in mind, the project also seeks to incorporate drone autonomy. To achieve this goal, and as mentioned before, the drone will be incorporated with several thermo sensors as well as computer vision navigation, in contrast to supervised navigation in [4].

In [cite3], the paper dives into the design of the UAVs and features that have to be taken into account so as to create a successful model. [5] poses an argument for frame materials that can withstand the heat expelled by fire, the fire extinguisher payload (2.5 lbs.), and sustain proper speeds. Additionally, the team believes that wind speed should also factor into the design considerations. [5] also considers the structure configuration of the UAV, suggesting a hexacopter. The hexacopter design allows for system redundancy in the case that a motor/propeller fails. It also allows for better payload management. The team is interested in pursuing this design avenue. Another design option kept in mind is the quadcopter design. This design is heavily used by the industry and is an option the team is willing to pursue due to the mechanical simplicity and cost efficiency. Additionally, other key points [5] touches upon is range communication and collision avoidance. As mentioned before, this project will seek to address these features with an RFID scanner and computer vision algorithms, respectively.

Conclusion

The research papers discussed in this literature review allowed for the team to address mechanical and software design key points. It also created a bigger picture in terms of possible difficulties and provided several paths that can be explored during the development of the UAV Fire-Fighting system. Considering the decisions made in the papers discussed, the team was also able to encounter areas of improvement in previous projects.

Project Goals

The goal for this project is to create a drone that will be able to work in unison with firefighters. This drone will be able to locate fires and put them out completely autonomously. By designing, programming, and fabricating this drone we hope to learn how to use neural networks and computer vision to optimize the effectiveness of the drone. The idea behind a neural network is to use the information that we receive from convolution to pick the most useful piece of information from the data that is created during the n^{th} trial. While we are picking the beneficial set of data points from the $(n^{th} + 1)$ trial, during the subsequent trial the previous data point would be used for comparison. The two trials are then compared by using convolution to heed the best result and will continue to do so as progress is being made. This is applied to the fire safety drone through camera vision. As the trials proceed the object recognition of the camera will improve in order to better recognize the attributes of a fire. This will be through the color of the flame while also being trained to ignore any background information that is not needed. While the camera is being used to understand the image of fire it will not be able to detect the heat signature produced by the flame in the same fashion as a forward-looking infrared (FLIR) thermal imaging camera. Using this version of image recognition along with a thermal sensor. The thermal sensor will be used to detect if the source in question is in fact a fire. The thermal detects infrared light between 760-1100 nanometers with a range of ~1 meters and a deflection angle of 60°. With this range whenever we detect a supposed fire we would be able to close in on the target location and use the sensor to determine if it is a fire. While flying towards the location the drone will also utilize rangefinders to act in the place of the object avoidance system. Having sensors on all sides of the drone will allow us to always make sure that there are no animals that are obstacles that can cause harm to the drone or the area around it.

When designing the drone model it will help us better understand the mechanical engineering process of fabricating a product. The design process will give a better understanding of AutoCAD softwares such as Inventor or Solidworks along with giving us a better insight on material use. The material needed will need to be lightweight enough to be able to lift off and fly at a reasonable speed while also being resistant to high temperatures. Designing the drone will focus on the accuracy and precision of pieces to ensure that the flight of the drone is stable. This

extends to the type of motors used along with the propeller that are attached. Depending on the battery size there is an optimal motor rating to go along with it. The motor rating gives the dimensions of the motor along with the kilovolts. The kilovolts size is used to determine the RPM of the motor which is used to calculate the thrust it can output for the load size. Beyond choosing the correct motor size the propellers used need to be chosen in a similar fashion. The size of the propellers' pitch and diameter change how well the drone can move through the air. The larger the pitch, the further the propeller will move through the air with one rotation. But the right size of the propeller impacts the amount of current draw of each motor.

By the end of this project will have gained mass amounts of knowledge about both the hardware and software used while creating a drone. The combination of all of these aspects will provide skills that will be able to expand into a wide range of disciplines.

Methodology

This research project will explain the benefits of creating an autonomous drone that will be able to seek out fires and extinguish them appropriately. The drone will utilize cameras and thermal sensors in order to replicate how an infrared camera would operate. We aim to prove the effectiveness of an autonomous drone by measuring the time it takes to locate the problem area and extinguish the flame. We will also be able to calculate the efficiency of the drone by recording the amount stored materials vs the amount of materials used during each trial.

In order to fabricate an autonomous drone it will be completely designed and programmed for all aspects of the UAV. The drone is designed in autocad Inventor before going through a prototype phase. The Drone will be a quadcopter with a x-style frame and DC brushless motors with topside propellers. In order for the UAV to recognize the environment it will be fitted with Time-of-flight sensors, A camera, and ultrasonic sensors. The sensors will allow the drone to have an awareness of the environment around and be able to react accordingly with little human input. The ultrasonic and Time-of-Flight sensors will be used to tell whenever an object is in its vicinity or along its flight path and stop the drone from moving. In order to sense a fire the drone will use the camera and a thermal sensor to detect the fire in a similar fashion to a IR camera. To help flight control of the system a PID controller will be implemented, a gyrometer, barometer, magnetometer, and accelerometer. These sensors will help

measure where the drone is in the world. The barometer measures the pressure around the drone in order to calculate the altitude, and the accelerometer will measure the speed of the drone. The gyrometer will record the orientation of the drone, and the magnetometer will measure where the drone is in relation to the magnetic fields. For the drone to extinguish fires, we will be using a spray canister. The spray canister discharges four times longer than traditional fire extinguisher products. It is safer and more effective than water as water has proven to make some fires worse and cause them to spread. The extinguishing formula found in the fire spray can extinguish grease, paper, fabric, wood, or electrical fires and it is biodegradable and easy to clean. It is compact and easy to use and so will be fitted in the drone where it will be easily replaceable for refilling. To operate the extinguisher a servo will be connected that will be activated when the drone is in range of a fire. Another servo will be used to move the spray canister in a sweeping motion as if there were someone using an actual fire extinguisher. As mentioned before, the drone should be able to operate with very little human input. Someone should be able to turn on the drone and when the time comes, exchange the spray canisters into the drone a safe distance away from the fire; the drone will take care of everything else accordingly. This process should go on until the fire is completely extinguished.

Project Breakdown and Tasks

The designing, testing, and fabrication of a completely autonomous drone that can locate and put out fires is a challenging task that will take weeks to complete. The tasks that are needed to be completed can be found on the Gantt chart located in the scheduling section of this paper. This project can be broken down into four sections: drone design, circuit design, neural network design, and programming components for communication. Drone design will be led by John Bailey with help from everybody else in the group if need be. The design process will take place in AutoCad software, using Inventor or SolidWorks to create the individual pieces needed to put the drone together. The circuit design will be led by Camiya Felton. The drone will be relatively small and there are many components that have to fit on and within the body in order for the drone to operate properly such as: flame sensor, four laser distance sensors, Raspberry pi, brushless DC motors, pixy2 camera, arduino, servos, and battery. Camiya will be challenged with creating a circuit that is able to power each individual component, allow for communication between each component and make sure it is compact enough to fit within the body of the drone. The neural network design will be led by Maria Gonzalez Bocanegra. The purpose of this drone is to be able to locate fires quickly and put them out just as fast. This will be done using a pixy2 camera in combination with a thermal sensor. The pixy2 camera will be trained to detect fires by their color using Maria's neural network and the thermal sensor will confirm if it's a fire by detecting its heat. Programming the components for communication will be led by Jamison Golson. As mentioned before, there are many components that have to communicate with each other in order for the drone to do what it is intended to do. With the heart of the drone being a raspberry pi, the code necessary to control the drone has to be written efficiently since there will also be a neural network running and the pi has limited storage space to work with.

Deliverables

When this project is completed we hope to create an affordable drone that can be used in all aspects of fire safety and prevention. Our main goal is to create a drone that when turned on can

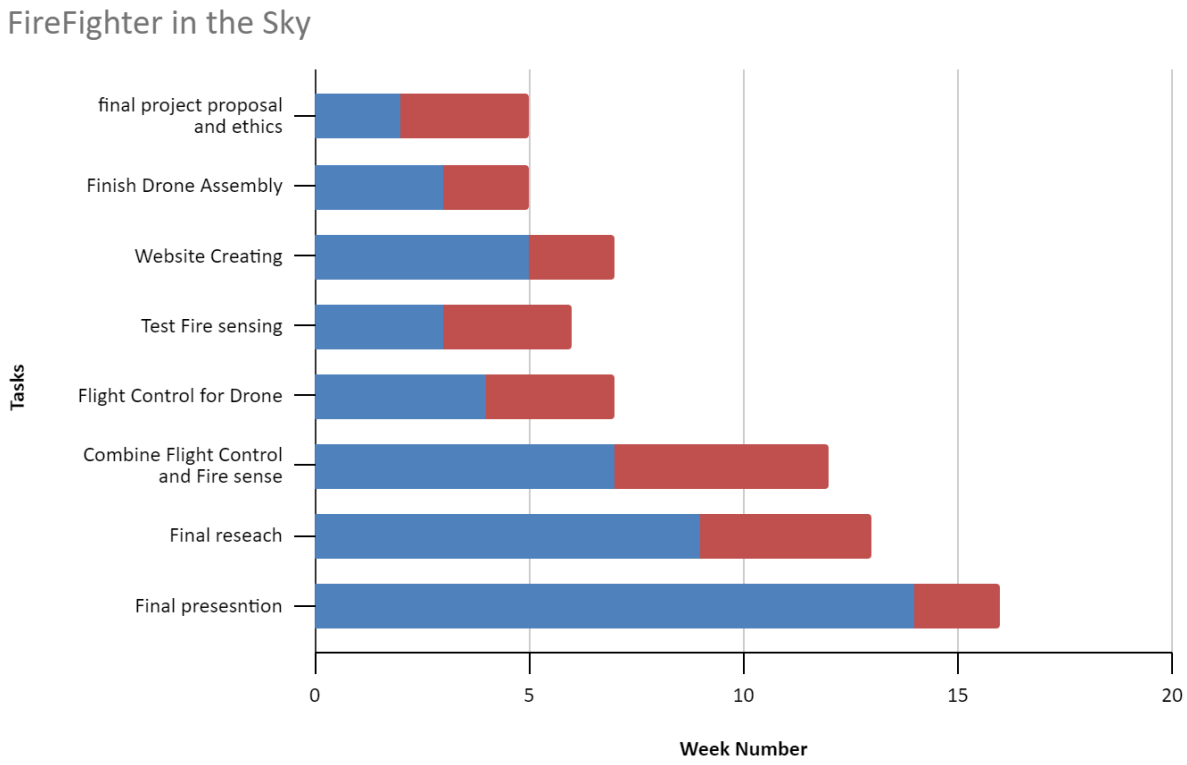
sense the environment around it and safely navigate to the area of a fire. Once the drone reaches the target location it will be able to extinguish the flame before returning back to home base. If the project was to continue on in the future then the drone would be equipped with a FLIR sensor in order to navigate to the fire automatically and carry out its task until all heat signatures above a certain value are treated and return to acceptable levels. This drone will be able to operate on a single building or a group and be able to assist in quelling wildfires. When facing a group of buildings or a wildfire a network or swarm of drones can be used to put out fires. If there is a large network of drones that will work in similar fashion to self driving cars, so that they are constantly communicating with each other when fighting the fire. This will allow for them to spread out and put out the flames in the most optimal way or target specific areas a human would not be able to reach. The drones would provide a sense of accuracy that a helicopter would not be able to obtain when it is dropping large amounts of water. Due to this increased precision there would be less water wasted, which leads to putting out the fire at a faster rate.

In future projects with the drone being equipped with a thermal imaging camera the use of it can go beyond extinguishing fires. The drone technology can also be used to take preventative measures for fire safety. If it is used for surveillance of a building it can detect abnormally hot or cold spots that a human would not be able to reach safely. This type of application is especially possible after storms where the structural integrity of the building may be compromised. After a storm there may be blockage in the AC units which could lead to a fire, and a human inspector would be at risk while searching a problem area. This type of drone could also be used to aid firefighters when they are searching for stranded survivors after disaster strikes. During a fire there is tons of smoke and confusion for anybody that is trapped inside. The thermal detection can help locate any humans or animals that may be trapped inside. After the drone finds a potential heat source it could then ping the home base system or controller to alert any firefighters in the vicinity to search that area.

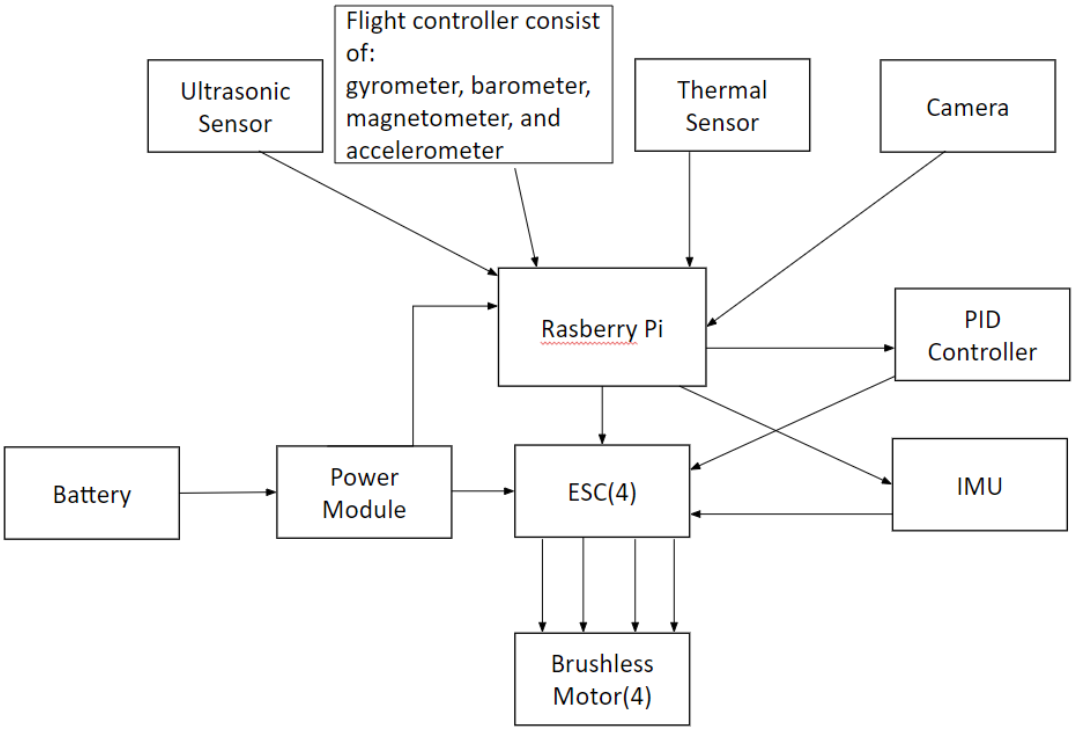
With the rise in the use of UAV technology there are a multitude of directions that the information can be applied. With the world already moving towards self-driving cars to streamline travel, robot delivery systems, using drones to help improve safety and prevention is the next step. Using drones to help combat a common disaster and help save lives is a much needed improvement.

Scheduling

Tasks	Start Week	Duration in Weeks
Final project proposal and ethics	2	3
Finish Drone Assembly	3	2
Website Creating	5	2
Test Fire sensing	3	3
Flight Control for Drone	4	3
Combine Flight Control and Fire sense	7	5
Final research	9	4
Final presentation	14	2



Block Diagram



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