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Semi Autonomous Firefighting Drone

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ABSTRACT

Most of the time fire occurs in unpredicted locations. It may occur in forest, buildings or in the middle of ocean. This paper talks about the extinguishing of fire using drones, fire accidents could be critical and accessing the situation at an early stage is very important in order to suppress the fire and evacuate the residents, as well as in the recent times forest and bush fires too have become a matter of concern which we face a hard time extinguishing as the fire fighters can't reach out to first in dense forests. In these cases, aerial robot platforms have advantages because of its ability to access the place that is hard to reach. This paper elaborates ways to develop a firefighting UAV that operates in a Semi-autonomous manner by using Monoammonium-phosphate (NH4H2PO4) payload as the fire extinguishing agent.

Keywords—*Quadcopter, GPS, Sensor, Motor, Extinguisher, Fire, Communication, Semi-autonomous*

1. INTRODUCTION

Fire fighters use an FLIR (Forward-looking infrared) thermographic camera for finding the fire. Firefighters first try to protect the people who are stuck in the fire and extinguish the fire.

The conventional firefighting involves the following:

(a) The fire fighters need to risk their lives. Both the victim and firemen are possible to get severely wounded in a worst situation.
(b) The incident may cause visual observation errors. It's not easy to find their way through many smoke screens created by fire.
(c) The decision maker(firemen) works in a hazardous and stressful environment.
(d) Even after surviving they suffer from severe burns and Post Traumatic Stress Disorder (PTSD).

Fire accidents are moreover like a natural disaster. In 2017, 3400 civilians died and 14670 people got injured by fire. The most recent fire accident, the Australian bush fire where more than 15.6 million acres burnt, 1400 homes destroyed and it killed nearly 1 billion animals.

This paper gives a brief proposal on combining the powers of a UAV and the powerful fire extinguishing properties of Mono-Ammonium Phosphate. The basic idea is to make a drone carry payload of Mono-Ammonium Phosphate, sense the fire and drop the payload accordingly in order to put out the fire or reduce the impact thereby giving more time for rescue operations and saving lives. Mono-Ammonium Phosphate has excellent fire extinguishing properties and the side effects are rather negligible. The problem faced by the UAV is limited flight time/power supply, & fireproofing in extreme conditions for which aramid fiber and air buffer layers can be used to minimize the effects.

2. LITERATURE SURVEY

There are many projects developed specifically for fighting fire. Some of them use firefighting robots, sprinklers, drones. The following projects were done using existing drones and a survey was made out of them.

2.1 Automatic CO2 Extinguisher Fire Fighting Drone

This paper addresses the problem of risk of fire fighters in the incident area and automatic firefighting area unit (which is used to prevent the fire place but the extinguisher does not seem to reach the required potential).In this FFE is equipped in the drone that consists of a Flame sensor SKU: DFR0076, buzzer, Intumescent paint and a CO2 extinguisher or compressed gas. When the sensor detects the fire it automatically opens the nozzle which releases pressurized liquid carbon dioxide. But it is not fully automatic so the UAV needs to be taken to an incident area manually before it starts its work and CO2 extinguishers cannot be used on solid fuel burning fires like paThis paper mainly addresses the problem of fires on boats in the middle of a waterbody where fire engines and the people can't reach the incident area easily. In this the pilot controls the drone from the base station. The drone contains a camera which is used for navigation. With the help of a camera we identify the source of fire. After identifying the source, we use FIREICE to

extinguish the fire. Uses a video feed system. But Consumes more power, suitable for only class A and B fires and user workload (fully manual).

2.2 Multiple UAVs in forest firefighting mission using particle swarm optimization

This paper addresses the problem for extinguishing the forest fires rapidly using multiple drones. In these fire spots coordinates are detected and sent to firefighting UAV teams. The firefighting team will receive relevant information and then they use an auction-based algorithm to solve the problem. The objective of the algorithm is to assign each UAV to each fire spot so that they travel a minimum distance.

Then each UAV will optimally plan its path by using particle swarm optimization (PSO) algorithm. With complex situations there is a possibility for the algorithm to be trapped into a local minimum making the swarm of drones to collapse and collide with each other.

3. ANALYSIS AND DESIGN

From the above survey we learn that the drone should have the proper fire extinguisher, better communication, suitable dropping mechanism etc.

3.1 Extinguisher

Extinguisher is decided by fire class. Fire class is used to denote the fire type, in relation to the combustion materials that have ignited.

It will be classified based on the material burning like liquid, gas, metal, combustible material. It also includes electrical fires and cooking oils combustions.

- Class A fire involves solid materials such as wood, paper or textiles.
- Class B fire involves flammable liquids such as petrol, diesel or oils.
- Class C fire involves gases.
- Class D fire involves metals.
- Class E fire involves live electrical apparatus
- Class F fire involves cooking oils such as in deep-fat fryers.

As most of the fires are of class A, B and C we chose more portable and effective dry chemical (mono-ammonium phosphate) as the extinguisher payload for our UAV.

3.2 Fire Detection

The detection of fire is done by considering various analog reads from flame and gas sensors. The candidate parameters for developing a fire detector is done by taking into consideration not just the flame sensors values or the smoke surrounding the environment but also the concentrations of CO and CO2 where both of them majorly contribute to any given fire event. Strong level of CO and CO2 were detected in smoldering, flaming and burn tests of various flammables such as toluene, heptane, methanol, newspapers, acrylic sheets, and wood.

The algorithm in this paper uses derivatives of smoke levels with CO/CO2 concentrations

The flame sensor readings and rate of smoke is checked continuously if it exceeds a predetermined threshold and as well as the reading of the CO sensors reaches its own set threshold level then its a positive indication for presence of fire.

Or when the flame sensor itself goes off detecting a flame, it is another straight positive for presence of fire.

3.3 UAV Quadrotor

There are several types of multirotor drones, we have designed the drone to be a Quad Rotor and it carries ABC extinguisher as a payload.

Our aim is to design a semi-autonomous UAV which can detect fire and drop a payload of dry chemicals which could extinguish fire or reduce the impact thereby giving more time for the rescue operations. Flame sensors are used for detection of fire which can be swapped with industry grade sensors for more efficiency and range. A dropping mechanism is trigger when the sensor detects a flame during semi-autonomous planned flights, whereas we could drop the payload manually as well. The payload mono-ammonium phosphate (ABC dry chemical) can extinguish or bring down the impact of the fire by smothering it.

(a) F450 Quadrotor frame: It is the base structure of a drone. This is made up of glass fiber with 450mm quadcopter frame. The frame itself acts as a PCB for power supply to the motors. Hexacopter can be used for heavier payloads.

(b) Brushless motor 1000KV: These are specifically used for building motor crafts, needing a minimum of 18 amp of current. It provides 900gm's of thrust on a 11.1v battery.

(c) Self-Locking Counter Rotating Propeller Pair (10 x 4.5): These pairs are self-locking pairs. These propellers are rigid and intact even during crashes when properly installed.

(d) Electronic Speed Controller 30A: ESC's are used to regulate and coordinate the speed of the motors.

(e) Pixhawk Flight controller: Pixhawk being the brain of the UAV helps in synchronizing the motors and being pre equipped with Gyroscope, Accelerometer and a Compass helps the UAV to have a stabilized flight and also supports wireless telemetry connections up to several kilometers, has GPS ports and UNIX programming capabilities which all can be monitored and altered by using any ground station application like Mission Planner, APM Planner, etc.

(f) APM Power Module with XT60 Connector: It is used for supplying the regulated power to the pixhawk and other components. It also measures battery voltage and current consumption.

(g) Six Channel Transmitter and Receiver: These are the transmitters and the receivers. The receiver will be connected with the flight controller's RC-IN, 6 channels are available for different functions and movements.

(h) UBLOX NEO7M GPS with compass: It is used externally for location services. It removes interferences from other signals providing more accurate GPS location and also has an external compass apart from the Flight controller's integrated one.

(i) 433MHZ Telemetry 250MW 2KM range: These pairs where the AIR module is attached to the drone and the ground module to base station (PC). This helps in establishing wireless connection with the flight controller when the UAV is in flight for monitoring the parameters and also for planning automated missions.

(j) Arduino Uno: We are using this well-known microcontroller for extending the capabilities of our UAV to exhibit collision avoidance using for overriding the RC channel's movements and move accordingly based on detected obstacles and the servos for payload and flame sensors are as well controlled by the UNO Board.

(k) Ultrasonic sensor HC-SR04: It uses the ultrasonic waves to measure the distance of objects, helps in detection of the obstacles on the way and triggers the Arduino which inurn overrides the Flight Controllers movements to dodge away from the obstacle.

(l) Flame and gas sensors: The Flame sensors used works on Infrared flame ranges, though it is suggested to use industry grade FFE sensors for better accuracy and range, as the flame sensors that are used are low in range. And for better efficiency the MQ9 and MQ135 gas sensors were used to detect CO and CO2 levels.

(m) Servo Motors: These are used to implement the dropping mechanism of the payload.

4. IMPLEMENTATION

Considering all the above specifications, the Quad can be designed by following the below steps:

Step 1: Assembly of Quad frame: Arms need to be screwed on the bottom plate before the top plate. Now the plates are mounted for the motors.

Step 2: Mounting the motors & speed controllers: Mount the motors on plates facing inwards with hex screws. Solder the ESC's on the power distribution board.

Step 3: Mounting the electronics: Fix all the ESC's & power distribution board to the frame and connect all the ESC's to the corresponding motors and finally the flight controller is well fixed on the frame on top of an anti vibrator for compass stability.

Step 4: External Components: Place the GPS module and the telemetry at the required positions in the frame and strap them tight before plugging them into the Flight Controller. Connect the receiver module to the FC via the PPM encoder.

Fig. 1: Our quad after mounting the motors and essential components

Step 5: Initial Calibration of the UAV: Using Mission Planner Application as the base station for quad, connect the Pixahwk FC via USB or telemetry to the PC and start calibrating the quad starting with the Accelerometer, and Compass and the ESC's and finally calibrate the Radio as well. Finally do the motor testing to find the range at which throttle all them motors spin.

Step 6: Mounting the Microcontroller and HC04: Now connecting the HC04 ultrasonic sensors to the Arduino UNO and programming it to receive the distances, setting a threshold distance to be avoided by the quad and powering the UNO via the Aux Power output from Pixhawk, placing the Ultrasonic sensors on all four directions mounted well above the FC we connect the TX and RX pins to one of the serial ports of the FC for altering the RC commands whenever an obstacle is detected.

Fig. 2: The quad with the UNO and collision avoidance system on top of FC

Step 7: Installing the Flame sensors and Servo Dropping Mechanism: Now finally along with HC04 the analog pins of the UNO Board are used to receive flame sensor and gas sensor readings and also a simple servo motor is used to hold up a container with the payload closed by a hinge joint to open up when the flame sensor is triggered.

Step 8: The first flight: Arm the Drone in an open area for the first flight, observe the stability and how well the calibration is and make changes accordingly.

Fig. 3: Image from our recent test flight

4.1. Hardware

a. Power supply: The Quad copter is powered by LiPo batteries of desired mAh depending on the required flight time and the technical capacity of the motors to provide enough thrust.

b. Obstacle avoidance Modules: The HC-SR04 ultrasonic sensor is fixed on the top frame. It produces the analog output which is processed by the microcontroller and overrides the flight controller's commands to the quadcopter.

c. Wireless Transmission with Telemetry Module: This plays a prominent role in communicating with drones allowing to control them with a PC as a base station using the Autopilot software (ARDUCOPTER) without RC channels.

d. Infrared Flame and Gas sensors: Used for detecting the Flame/Gas and reporting back to the microcontroller.

e. Fire Extinguishing Mechanism: Here we use a dispatching mechanism of the (mono ammonium phosphate) payload using required servo motors when the flame/gas sensor detects the fire.

f. Fire Proofing: Though the drone will not get in direct contact with fire Aramid fiber skin can be used to cover the drone which protects it from heat and slight flames to ensure

the electrical components of the drone are safe while operating.

Fig. 4: Image of extinguishing fire using ABC fire ball

Fig. 5: Image of fire proofing with aramid fiber

4.2 Software

4.2.1 Mission Planner Application: Mission Planner is the software designed by ArduCopter which we are using as the base station controller for our UAV apart from being used for calibrating the drone and monitoring status of the UAV it does more, some of them listed as follows:

- Point-and-click waypoint entry, using Bing/Google Maps/Custom WMS/Open street maps.
- Select mission commands from drop-down menus.
- Download mission log files and analyze them.
- Configure APM settings for your airframe.
- Interface which contains PC flight simulator is used to create a full hardware-in-the-loop UAV simulator.
- Sees the output from APM's serial terminal.
- Helps in Planning GPS based autonomous missions using custom waypoints.

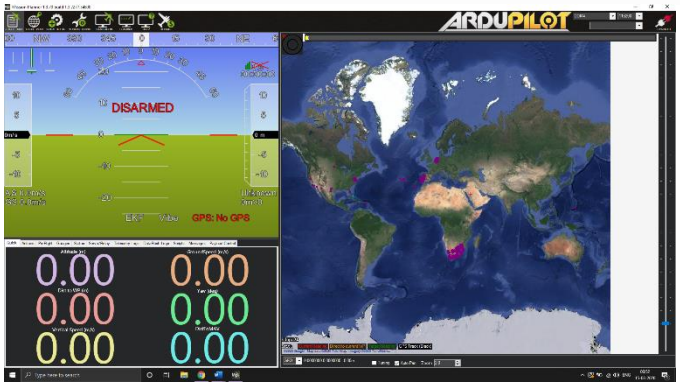

Fig. 6: Image from our mission planner application

5. CONCLUSION

Without involving the risk of firefighter's life this model can be used for many purposes to extinguish the fire and it can be quicker than the firefighter's actions. In future we decide on upgrading the drone to be capable of working as master and slaves of swarm-based fire fighters using development boards such as the PARTICLE Argon/Xenon IOT Boards. And with better frame quality of withstanding the heat made of carbon fiber and using various cameras for monitoring purposes.

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