UAV FIRE EXTINGUISHER

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ABSTRACT

The ignition of certain materials that combust to create a fire is something that most of the times occurs without being wanted. The damages that a fire causes are proportional to the size of the fire. Sometimes, nothing happens to property and living beings, but other times, the emotional and economic losses are too great to afford to keep having fires that are difficult to control, and eventually extinguish. For that reason, the intention of this design project is to improve the ways in which fires are prevented and extinguished. UAVs are apparatuses that have become popular in recent years thanks to not only their many capabilities to program, but also that a human being does not need to be on board in order to control it. Hence, this team decided to use them in an innovative and inventive manner to create a mechanism to release a fire extinguishing grenade in the desired location that will prevent fires or directly extinguish them.

Keywords : *UAV, UAS, UGV, Forest fire, Fire extinguisher, Extinguisher grenade*

1. Introduction

Unmanned aerial vehicles (UAV) are more properly known as Drone [1]. Drone stands for Dynamic Remotely Operated Navigation Equipment. A Drone, also called a Quadcopter, is a multirotor helicopter that is lifted and propelled by four rotors. Most of helicopters, Quadcopter use two sets of identical fixed pitched propellers; two clockwise (CW) and two counter-clockwise (CCW). These use variation of RPM to control lift and torque. Because of its unique design comparing to traditional helicopters, it allows a more stable platform, making Quadcopter ideal for tasks such as surveillance and aerial photography. And it is also getting very popular in UAV research in recent years. Control of vehicle motion is achieved by altering the pitch and/or rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics. This paper serves as a solution to handling the quadcopter with angular precision by illustrating how the spin of the four rotors should be varied simultaneously to achieve correct angular orientation along with standard flight operations such as taking-off, landing and hovering at an altitude [2][3][4]. Fire is crucial for the development of human society, and it has become an important part of human civilization. Among different types of disasters, fire constitutes a significant threat to life and property in urban and rural areas. Fires that occur in homes and non-residential buildings as well as fires in wild lands cause plenty of health issues; including death to humans and animals, in addition to great economic losses in structures, equipment and vegetation. Furthermore, the first response teams, such as fire-fighters, are exposing their lives to great risks in order to extinguish a fire. One of the most popular ways to extinguish fires is to spray water in the area affected by the flames. The water can be delivered via hose using a pressurized fire hydrant, fire sprinkler system, pumped from water sources, such as lakes, rivers or tanker trucks, or dropped from aircrafts in the case of wild land fires. In order to help those that risk their life when a fire takes place, the living beings that can be potentially harmed and their surroundings, such as edifications and forests, to preserve the goods inside a building once a fire occurs, and to help avoid fires in open spaces.. From the Literature survey The beginning of the development of remote controlled devices started with the invention of the radio, back in the 1880's, when Nikola Tesla invented the induction coil, a necessary device to send and receive radio waves. At first, these radio signals were intended for communications purposes, but during World War I the Germans started using remote control stations for manipulating tanks loaded with explosives [5]**.** Between 1914 and 1918, the development of various radio controlled unmanned aircraft were intended to be used for military purposes; however none of the prototypes was fully functional to be used during the war. This also marked the beginning of the use of radio waves for commanding machines and computers, such as power plants and satellites [6]. Thus, the development of small autonomous flying, i.e., aerial vehicles for indoor or urban applications, able to perform agile flight inside buildings, stadiums, stairwells, airports, train stations, ventilation systems, shafts, tunnels etc. is of significant importance [7]. With the culmination of the programmable digital computer in the 1940's, the idea of having a totally independent machine has been the subject of multiple studies. Technological advances in the performance of sensors were seen between the 1950 and 1990, improving the response for their tasks, which were mainly surveillance, bombing, and pilot training. It was not until the introduction of the GPS in the 1990's that UAVs took a major role in not only military but also civilian objective. In these last years, the U.S. is spending more than $50 billion annually in UAV development and testing. This covers from drones to weather balloons, but advances in UAVs for fire fighting technology has not been put together yet [8][9][10]. The time to suppress a forest fire is critical with regards to the fire burden consisting of economic, environmental, and social losses. Although the ongoing research on using UAS to detect wildfires has shown promising progress, the development of such systems, including software, hardware, and applications, is still at a minimum [11]. To decrease the fire burden, currently UASs are used by several fire departments nationwide for search and rescue operations, and for situational awareness assessed by monitoring (finding a potential fire or hot spot), detection (triggering an alarm to inform related operators and personnel), diagnosis (determining the fire's location and extent and tracking its progress), and prognosis (predicting the future of the fire) [12]. Ground measurement equipment may suffer from restricted surveillance ranges, and manned aircraft are typically expensive. The fire-fighter's need for frequent and high quality information with regards to fire behaviour could be achieved by autonomous UAS even under low light and high smoke conditions by means of the embedded sensors with low cost [13].

Visual cameras, on the other hand, have been used to detect the smoke produced by fire under daylight conditions. Visual cameras can mainly provide flame height and angle, and fire's location and width. Fire detection with visual cameras is mainly based on contrast, texture, and motion analysis [14]. Another early method is the use of light detection and ranging (LIDAR) devices to identify the concentration of fire smoke particles [15].

On the other hand, Lee et al., evaluated five deep convolutional neural networks for detection of wildfires [16]. The majority of the deep convolutional networks were identified to be effective in detecting wildfires by analysing aerial images. Dios et al., (2011) tested UAS under several scenarios measuring sources of errors in detecting the forest fires with infrared and visual cameras. Although the ongoing research on using UAS to detect wildfires has shown promising progress, the development of such systems, including software, hardware, and applications, is still at a minimum.

The first set of studies used or recommended the use of water as the fire suppressant. One of these studies was conducted by Lockheed Martin by demonstrating a collaborative system including a UAS and a helicopter. The hot spots identified by the UAS were attacked by the helicopter by dropping water [17]. Several other companies, such as Aerones, Nitrofirex, Singular Aircraft have also been working on developing drone systems that utilize water to suppress building or wild fires [18–20]. Phan and Liu (2008) proposed a system including an airship, UAS and unmanned ground vehicles (UGVs). The airship, which is the top level of the hierarchy, generates a mission plan by utilizing wildfire, UAS, and UGV dynamic models. It sends commands to the UASs and UGVs to travel to certain waypoints for them to suppress the fire. This system has not been tested in real life, but simulation tests have been planned albeit not executed yet [21].

In a simulation study, Kumar et al. developed a control model for multiple UASs to detect the fire front and also to fight the fire with limitless fire suppressant fluid [22]. They tested their model with use of 10 UASs via simulation. Yet, their system has not been tested in a real life scenario. Also, the assumption of limitless suppressant fluid is not practical. As undergraduate design projects at Florida International University (FIU), a student team designed a quadcopter with a ball-throwing mechanism that can shoot a single unit of fire-extinguishing ball by using compressed springs [23], whereas another team designed a claw mechanism to drop a unit of fire extinguishing ball [24]. None of the teams tested the mechanism attached to UAS. In another study conducted at FIU, a UAS design and a leader-follower algorithm were proposed to model the use of a swarm of UAS simultaneously dropping fire extinguishing balls to the wildfire [25].

In order to serve those that risk their life when a fire takes place, the living beings that can be potentially harmed and their surroundings, such as edifications and forests, to preserve the goods inside a building once a fire occurs, and to help avoid fires in open spaces, this team decided to focus this senior design project in the development of an UAV that is going to prevent fires and also assist in extinguishing them.

2. Materials and components

The materials and components consists of hardware materials, electronic and mechatronic components. In our project UAV fire extinguisher, the material used to for quadcopter frame is Ceramic fibre. Ceramic fibres are non-metallic inorganic materials consisting of metallic and non-metallic elements. The ceramic fibre is chosen for its high temperature handling properties. The ceramic fibre can sustain a maximum temperature of 1400^{o}c. As this is a fire extinguishing quadcopter this is apt for the frame construction. They are having a lighter weight when compared to aluminium and other steel materials. This is followed by the fibre glass, which is a high performance engineering material which has been widely used due to its high stiffness and strength. The glass fibre laminate has the advantages of high mechanical strength, good corrosion resistance, sound flame resistance and humidity resistance etc. laminate materials, is made from woven glass fibre fabric impregnated with epoxy This type of laminate composite can be used in a variety of applications including insulating structural parts in electrical equipment, vehicle and boat structure, marine structure, pressure vessel, container, gas pipe, aerospace structure. Light weight Aluminium bar is used as landing gear.

Components required for the quadcopter are BLDC, Flight controller, ESC (electronic speed control), Voltage regulator, Servo motor, Li-Po battery, alkaline battery, propellers, transmitter and receiver, fire extinguishing balls, cables and connectors. According to the application of quadcopter/drone the selection of brushless DC motor has to be done. If the quadcopter is carrying heavy payload, then the motor that produces high thrust is selected. This variations depends upon the KV of motors. Here the motor used is out runner motor which has a high efficiency. The out runner motor means that the coils in a motor remain as stator and the magnets are on the rotor side i.e. outer shell of the BLDC motor rotates. The motor used is Avionic 850 KV C2830. Flight controller is the important component in a quadcopter. It is said to be the heart of the quadcopter. It's function is to control the quadcopter movements as per programmed when the signals are being sent from other electronic components on a quadcopter. The flight controller consists of different sensors company installed in them. It also helps the quadcopter to sense the conditions as per the situation. The sensors that is present in the flight controller are gyroscope, magnetometer, accelerometer etc. Some flight controller allows to add on the sensors. The flight controller used is KK 2.1.5. ESC are said to control the seed of the motors on a multicopter or quadcopter. It helps in maintain the constant speed of all 4 motors in case of quadcopter. ESC also responds to the commands from the flight controller when the quadcopter motion changes with wind. For our project we used the 20 amps esc. In our model the voltage regulator is used for working of the servo motor. The voltage regulator function is to step down the voltage, before reaching the components. For dropping mechanism we use the Servo motor. The servo motor is a component that consist of arrangement of small gears which is well enough to produce the suitable torque. The servo motor at an voltage of 4.8 can produce a torque upto 2.5 kgf-cm and range upto 3 kgf-cm by increasing the voltage to 6V. According to the application, we chose the

Li-Po battery. It is a 3-cell battery that are packed together. The battery used is of 2200mah and having a capacitance of 25 (25c). The 9V battery said to be the alkaline battery is used for the working a servo motor. Other reasons to have higher thrust is the selection of the propellers. Larger the size of the propellers, higher the thrust. By using the larger size of propellers, the current draw from the battery also increases resulting in the quick drain of battery. In our model as per requirement 10” x 4.5” propellers are adopted. As quadcopter is flying vehicle and said to have no human pilot on-board, the controls and communication between the quadcopter and the operator have to be done with the transmitter and the receiver. In short, they are called as TX and RX. The fire extinguishing ball is a sphere-shaped product made of Styrofoam filled with environmentally friendly non-toxic chemical powders. The manufacturers

Claim that the ball self-activates within at least 3 seconds of contact with the fire; explodes and releases the extinguishing agents used as to extinguish the fire. There is dry chemical ABC powder also called by its chemical name as mono-ammonium phosphate (non-toxic). The overall connections in the quadcopter are done with the suitable cables and connectors. An AFO fire extinguishing ball can weigh 500 grams or 0.5kg.

3. Step by step Procedure

First we need to decide the configuration of the quadcopter. There are many types of configurations such as plus, X, etc.

As X- configuration is easier is fabrication and which offers good control, we selected the above configuration.

Now, as per the dimensions in **Table 1** the ceramic fibre is cut and the holes are drilled. There is a hole in the centre of 2 ceramic fibre frame. The 2 ceramic fibre frames are seen that perpendicular is maintained by using the leveller. Now both are tightened by using the screw. So, on each ceramic fibre frame there are 5 holes.

For holding the electronic components, we cut a square section of the fibre glass to a specified dimension. This fibre glass plate has to be fixed with ceramic fibre frame by using the bolt and nut. Now the 4 DC brushless motors are placed at appropriate position on each ceramic fibre arm on 4 sides. They are fastened with the bolt and nut. There are 4 ESC's, where all the positive terminal of the ESC's are connected and all the negative terminal of the ESC's are connected to power distribution board. From power distribution board we get one positive terminal and one negative terminal which then connected with the female connector.

Table 1

Dimensions of Frame (in mm)

Material	Length	width	Height
Ceramic fibre	450	40	3

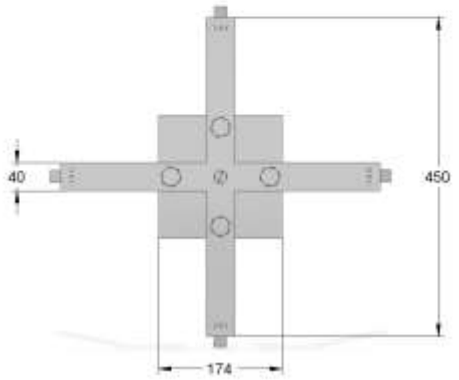
On the other side of ESC's there are 3 terminals, these 3 terminals are connected to the motors 3 terminal end using a bullet connector. The connection from a ESC to BLDC is connected properly so that it does not change in the rotational direction of the motor. As of quadcopter, 2 motors in CW and 2 motors in CCW is required. A housing for the battery storage is made above the frame. Above the battery storage, the flight controller is placed in a proper position. To know which is M1, M2, M3, M4, it is better to name them on the frame. In a KK 2.1.5 flight controller, there is a small arrow showing on the board which means it is the front of the quadcopter. There are 4 outputs from the ESC's, where it is passing with the jumper wires. Each wire is having response with the motors. In a flight controller input side, there are 3 column. They are Signal, + 5 , minus or ground. The connections are made for all the jumper wires that are emerging out from the ESC to the signal column of the flight controller. On out of the flight controller, the connection is made to the receiver. By using the jump wires, the connection between the flight controller output end and the receiver is made in sync. So there are totally 6 channels in the receiver where all are to be connected. The servo motor connection is made, where it have a separate PCB in which the voltage regulator is used. As the servo motor works at 5V, there is need in stepping down the voltage from a 9V alkaline battery using a 5V voltage regulator. From a servo motor the cable is connected to the battery connector and by soldering signal cable is connected to the voltage regulator. From voltage regulator, the signal cable is connected to the signal column. A small hollow PVC pipe is taken with pass through holes at it transverse section. This is made to arrange the servo motor mechanism. There is a small lever in a servo motor, which has to be adjusted with their movement and glue to the fibre glass. The landing gear is fixed using the light weight aluminium bar. The landing gear is designed and fixed in a manner to absorb the shocks while landing.
The binding of TX and RX has to be done.
Radio transmitter can only communicate with the radio receiver if two are binded. So the binding of transmitter and receiver is done by connecting the loop cable in receiver. Now connect all the motors and press the bind button of TX for 5 seconds. Then remove the battery supply and the loop cable. Again reconnect the battery and through the response we can see that TX and RX binded. For synchronising all 4 motors the ESC calibration is to be initialized.

For making the motors to run at different speed during tilt or any wind disturbances, the PI values are set in the Flight controller following the menu PI editor which is having the in-built display. PI values are shown on **Table 2** below

Table 2			
Flight controller: KK 2.1.5 board			
PI editor			
	Axis roll	Axis pitch	Axis yaw
P gain	75	75	75
P limit	50	50	50
I gain	40	40	40
I limit	20	20	20
Mode settings			
Self level	Link roll pitch	Auto disarm	CPPM
Aux	No	Yes	No

4. Design and Calculation

Design of quadcopter



Description	Length	Height	Width
Frame surface to ground	-	150.03 mm	-
Landing gear (Bar)	21 mm	20.13 mm	20.13 mm
Angle between the frame surface and the landing gear	32.4^o		

Thrust calculation:

Static thrust [25]

$T = (2 \times \pi \times R^2 \times rho \times P^2)^{0.3333}$

Table 3		
Material : Ceramic fibre		
Description	Length	Width
Frame (end to end)	450 mm	40 mm
Fibreglass (Square)	174 mm x 174 mm	

T = Thrust

Propeller diameter = 10”

Propeller radius [R] = 0.127m

$R^2 = 0.0161m$
From motor specifications
Power = 250 watts
BLDC Motor = 850 kv
Air density (rho) = 1.22 kg/m^3

Calculations:

$T = [2 \times \pi \times 0.0161 \times 1.22 \times (250)^2]^{0.3333}$

T = <u>19.75</u> N

Therefore, the thrust produced by 4 motors under static condition on the quadcopter is 19.75 N
19.75 x 101.9716 = <u>2013.9391</u> grams.
<u>Quadcopter flight time calculation</u>:

Calculation:
Quadcopter flight time = [(Battery capacity / Battery discharge) x 80] / [(Average ampere draw)] x [60]

Li-Po Battery – 2200 mAh

ESC amps – 20

Quadcopter Flight time =

[(2200 / 1000) x 80] / [20] x [60]

Quadcopter Flight time = <u>5.28 minutes</u>

5. Working Model

6. Testing of Model

7. Results and discussion

Initially the experiments were made to fly the quadcopter with high stabilization. For that we need to check the COG, and any changes in the PI editor settings. Once those are set to appropriate values then we can see that the quadcopter hovers with good stability and handling too. Then the payload was added where we had to look after the configuration settings again for a drone to lift without any disturbances. For dropping mechanism, the servo motor response was slow where it had to be tuned using the T6 config software. It was noticed the quadcopter without payload can hover for 7 to 9 minutes where with payload of 0.75kg it can hover for 5 to 7 minutes. We also made sure to install the landing gears with layered rubber washers which can prevent the shocks parallel for its load. Due to connection problems it was seen the motors malfunctioning which can be resolved.

8. Conclusion

Quadcopter is a special kind of vehicle, which can be implemented in different applications. In this paper basic principles of quadcopter design as well as current applications are represented. In the future applications, quadcopter could be used for a variety of new policing functions. Stabilization of attitude of the quadcopter was done by utilizing a PI controller. In this project we came to understand the flight principle of quadcopter and its usage. From the previous journals, it is known that the UAV's can be done in many modifications. We had done the mathematical calculations that is required for a quadcopter thrust. This project is mainly aimed for extinguishing the forest fires, open space fires and the fires that are not reachable by humans. This quadcopter can also used for the delivery of necessary commodities. So, we can say that this project can be used for reuse, fire fighting, mapping. This prototype project can be implemented in fire department that will be effective in extinguishing the fire and rescue operations. As we know the pilot of quadcopter requires special skill, there might be the job opportunities in the fire department.

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