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Advanced Autonomous Unmanned Aerial Vehicle (UAV) System with Real-time Monitoring, and Effective Suppression of Fire Emergencies

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Abstract: In this proposed system, a UAV and remote-sensing technologies are used in conjunction to support conventional firefighting techniques. This research investigates the potential usage of fire extinguishing balls. The proposed system consists of three parts: (1) a scouting Unmanned Aerial Vehicle (UAV) that uses remote sensing to spot fires and monitor the risk of a wildfire approaching a building, a fence, or a firefighting crew; (2) a communication UAV that establishes and extends a communication channel between the operator and the fire-fighting UAV. The goal of the vehicle is to locate and put out accidental fires using extinguishing balls, which can reduce the risk to humans to the absolute minimum.
Keywords: UAV, Fire, APM (ArduPilot Mega), Claw, Hexacopter, Extinguishing Ball.

I. INTRODUCTION

The primary objectives of fire fighters are to put out fires in order to safeguard and save lives as well as property. Trucks, ladders, and water pumps were often used up until recently in many locations. However, these are gradually being replaced with firefighting UAVs. UAVs are more effective in putting out fires when compared to older techniques. Firefighters are considering UAV technology to aid in their objectives because of rapid urbanisation and industrialization, traffic, larger structures, and more harmful compounds being utilised in construction [1].When a fire breaks out in a rugged area, it is quite difficult for firemen to put it out as quickly as possible. As an alternative, UAVs can fly to the targeted fire area, drop fire extinguisher balls, and then return to the starting place. Consequently, this method of firefighting is significantly safer than the conventional approach [2]. UAVs could prove very helpful in the firefighting process by offering firefighters an aerial evaluation of the scene to help them determine the severity of the fire. This would boost situational awareness. In order to avoid harming humans, UAVs may also be used to access challenging regions, particularly in dangerous circumstances. UAVs that are equipped with thermal cameras can also help firefighters locate hotspots by providing thermal assessments. [3]. Unmanned aerial vehicles (UAVs) are used to put out flames in difficult-to-reach or hazardous regions.

They can be used in many different circumstances, including as wildfires, industrial fires, and even house fires. The following are some potential advantages of employing fire extinguisher UAVs:

1) *Faster Response Times:* UAVs can arrive at the scene of a fire faster than roads and start suppression operations, potentially cutting down on the amount of time it takes to put out the fire, due to the reduction of traffic when the aid travels through air.
2) *Enhanced Safety:* Firefighters can lower the chance of injury by using UAVs to avoid entering potentially hazardous or dangerous environments.
3) *Greater Precision:* UAVs can be fitted with thermal cameras and other sensors to assist in locating the origin and the victims of a fire and more precisely directing suppression efforts.
4) *Cost Reductions:* In some circumstances, deploying UAVs to put out fires may be more economical.

Extinguishing a fire entails not only putting out the flames but also supporting operations including building firewalls, access points for cars to enter and exit, runways, heliports, etc. Humans were involved in these activities in Spain between 2006 and 2015, accounting for 100% of fires, 94.8% of ground vehicles and machinery, and 23.5% of aerial methods [4]. Extinguishing activities are risky since any accident could result in serious injuries or even death. Spain's government estimates that there were 24 incidents between 2006 and 2015 and 37 fatalities, all of whom were firefighters.

This analysis found that the leading causes of these fatalities were air accidents (43%), entrapments (30%), health issues (8%), falls (8%), vehicle accidents (5%), and mechanical accidents (5%)[4]. Therefore, it would be beneficial if technology solutions could lower the accident rate as well as mortality in cases of entrapments and falls, which can be brought on by a lack of knowledge about the course of a fire and the characteristics of the terrain.

Speaking of UAV technology, the decisions for using UAVs for fire extinguishers can be well defended because UAV deployment has been a successful technology in a variety of industries and applications.

One of the primary benefits of using UAVs for deployment is their ability to access areas that may be difficult or dangerous for humans to reach.

This includes inspecting infrastructure such as bridges, pipelines, and power lines, as well as performing search and rescue operations in remote or hazardous environments.

Other than these, some specific areas in which UAVs have helped other industries flourish include:

a) *Agriculture* - UAVs have been used to efficiently and accurately apply fertilizers, pesticides, and water to crops, leading to increased crop yields and reduced costs. They have also been used for precision farming, which involves collecting data on the health and condition of crops, to optimize irrigation and fertilization practices.
b) *Construction* - UAVs have been used to survey and map construction sites, as well as to inspect and monitor progress on buildings and other structures. This has allowed for faster and more accurate analysis of data, as well as reducing the need for human labour in hazardous or difficult-to-access locations.
c) *Environmental monitoring and conservation* - UAVs have been used to map forests, monitor wildlife populations, and detect pollution. They have also been used to assess the impact of natural disasters and to monitor the health of ecosystems.
d) *Delivery* - UAVs have been utilised in the delivery of goods and medical supplies in remote or unserved areas. This has allowed for faster and more efficient delivery, as well as reducing the need for transportation infrastructure in areas where it may be difficult to build roads or other infrastructure.
e) *Photography and Videography* - UAVs have revolutionised the way in which aerial photography and videography is captured, allowing for stunning aerial views that were previously only achievable with expensive manned aircraft. This has opened up new opportunities for photographers and videographers, as well as for the film and television industry.
f) *Rescue and Surveillance* - Large areas can be quickly searched for missing people or lost hikers using drones with cameras and thermal imaging sensors. They can also assist in finding survivors in disaster areas or places hit by natural disasters like earthquakes, storms, and floods. UAVs can be used to monitor crucial infrastructure, huge events, and public spaces. They can aid security and law enforcement officials in crowd surveillance, suspect tracking, and the identification of potential security risks.
g) *Mapping and Analysis* - Drones can produce in-depth 3D maps of difficult-to-access areas like hilly terrain or regions devastated by natural disasters. This can make rescuers' plans more effective and help them spot potential dangers.
h) *Delivery of Supplies* - Drones can be used to carry essential commodities, such as food, water, and medical supplies, to individuals in distant or difficult-to-reach locations.
i) *Military and defence* - UAVs can be used for border patrol and other security purposes, as well as for reconnaissance, surveillance, and targeting during military operations. UAVs have also been employed for logistical and supply tasks, including supplying troops on the front lines with ammunition, medical supplies, and other vital supplies. By doing this, the risk to human pilots who would otherwise have to fly these missions may be reduced.
j) *Environmental monitoring* - The usage of unmanned aerial vehicles (UAVs) for environmental monitoring is growing as a result of their capacity to cover wide regions and deliver data with excellent resolution. UAVs with sensors may gather information on several environmental factors such as vegetation cover, water quality, and air quality. This information can be used to track long-term environmental changes and guide resource management decisions.

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II. METHODOLOGY

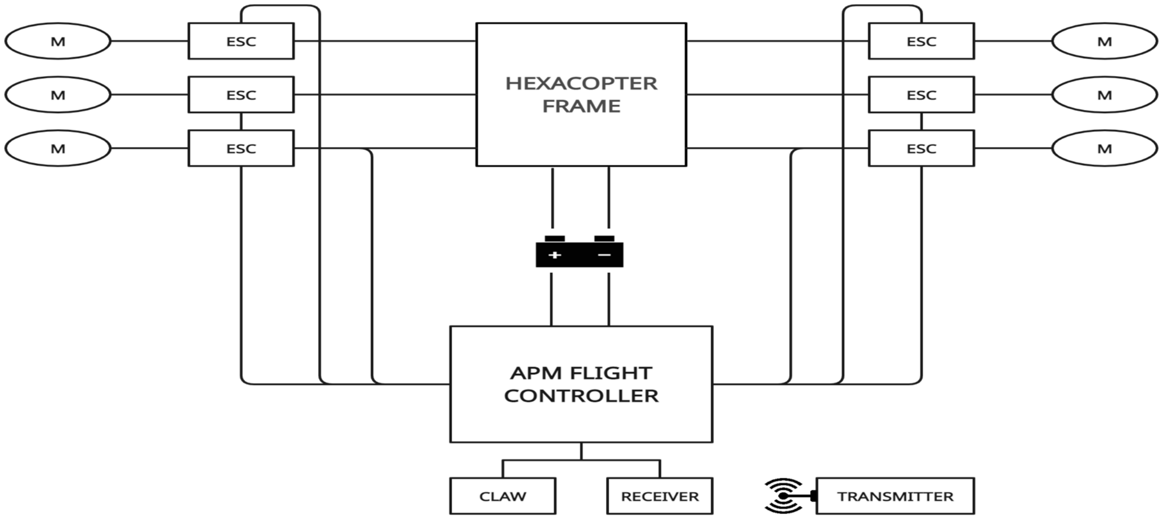

Figure 1: Block diagram showing the working principle of a fire extinguisher UAV.

The various units involved are as follows:

1) Hexacopter frame with landing gears.
2) Power supply unit (12.6V battery).
3) Motor (M) with 1400KV.
4) Electronic Speed Control (ESC).
5) ArduPilot Mega (APM) flight controller.
6) RC (transmitter and receiver) controller.
7) Claw mechanism.

The S550 hexacopter frame kit is a perfect lightweight solid Hexacopter frame with carbon fibre landing gear and a bonus built-in printed circuit board (PCB) for neat and easy wiring. It is a Hexacopter Frame that employs six arms to get into the air. The S550 has an intense, light, and sensible configuration, including a PCB(Printed Circuit Board) with which you can directly solder your ESCs to the frame. So, it avoids using extra PDB(Power Distribution Board) and makes the mounting clean and neat

The sequence of operation of the circuit is as follows:

a) An RC transmitter is used to provide the user input, or control of the UAV, it works on the 2.4GHz frequency band and has range upto 1000m (in the air).
b) This user input is received by a receiver and is fed to the flight controller.
c) As stated the flight controller is connected with the ESC as well as the motor with the help of which we can control the direction and the speed of the UAV.
d) The claw mechanism i.e the opening and closing of the claw is also controlled according to the user input with the help of the flight controller.
e) The battery is also connected with the Flight controller, ESC and Motor to provide the required power supply.

III. PERFORMANCE EVALUATION

The model needs the assembling and integration of the following components that are required in its construction which, consists of an S550 Hexacopter frame with landing gears, a propeller, M stands for a brushless motor with a constant velocity of 1400Kv, ESC (Electronic Speed Controller), a Lithium Polymer battery of 5200mAH, APM (ArduPilot Mega) flight controller, a RC controller and a gimbal for claw mechanism. Its general flight time is 25-30 minutes. All the enlisted parts are essential for the working of a UAV. In order to understand and evaluate the performing rate of the entire model, we briefly state the following component's main objective which they play respectively.

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The following integrals involved in the operation of UAV technology are:

1) The frame basically is the body of a hexacopter. Now its shape and the material used varies depending on size and design. In general cases a larger frame often has more arms than a smaller frame and a large frame is often built in carbon fibre or aluminium or both combined whereas a small one often is in plastic. The frame must be lightweight, sturdy, and affordable in order to make it congenial enough
2) Propellers are clove-like blade structured objects which are brought into play to create a difference in air pressure. When the propellers are in motion, they simply cut through the air creating a difference in pressure between the top and the bottom of the rotors during the process. The top side is characterised by low pressure as compared to the bottom causing the UAV to lift into the air. Usually the material chosen for the propeller is plastic as it is light in weight as compared to other materials.
3) A lithium polymer battery, or more correctly lithium-ion polymer battery is a rechargeable battery of lithium-ion technology using a polymer electrolyte instead of a liquid electrolyte. These batteries are amongst the most commonly used types for UAV technology as they are profitable in areas of providing high energy density and are less in weight when in comparison to other types of batteries.
4) The key element which functions a UAV working is the ability to control the motor's speed and rotation. Here we make use of an ESC (electronic speed controller) which is an electronic control board that varies or ranges the motor's speed. It also acts as a dynamic brake which is useful in the device. It is an electronic circuit that acts as the interface between the pilot's commands and the individual UAV motors. A signal from the flight controller causes the ESC to raise or lower the voltage to the motor as required, thus changing the speed of the propeller.
5) ArduPilot Mega is a fully programmable autopilot that requires a GPS module and sensors to create a functioning Unmanned Aerial Vehicle. The autopilot handles both stabilization and navigation, which hereby removes the need for a separate stabilization system. It also supports the fly mode which stabilizes an aircraft when flying manually, under RC control thereby making it easier and safer to fly. The hardware and software integrals both are open source. The APM circuit board comes with all the surface-mount parts already soldered on it, but requires an additional soldering on connectors by the user.
6) In the field of UAVs, the controlling part needs most of the attention and calibration part needs to be done correctly in order to provide vital signals to these UAVs and most other aerial vehicles. Some noticeable specifications about it is a digital proportional radio control system that operates on the global ISM band of 2.4GHz frequency, moreover the FS transmitter and receiver comes with its set of alerting system which allows us to fully customize the flight setting and use it in the basic UAV technology. [12]
7) Gimbal is an important element added into this concept which contributes in providing the claw action. It is a pivoted support mechanism that considers the rotation of an object about an axis. The gimbal executes the claw mechanism part while holding and dropping the extinguishing balls.

Figure 2: Proposed system for fire extinguishing UAV.

A. *Thrust Calculation*

To make sure that the right propellers and motors have been chosen, static thrust calculations are required. The amount of thrust generated by a propeller that is fixed to the earth is referred to as static thrust. Due to the likelihood that a hexarotor UAV will operate at low speeds in relation to the ground, this estimate is particularly crucial for this project. This low-speed capability makes it possible to use the static thrust calculations in a variety of flight scenarios. It's vital to remember that the static thrust estimations used in the final computations are estimates rather than actual numbers.

Thrust produced by propeller is given as:

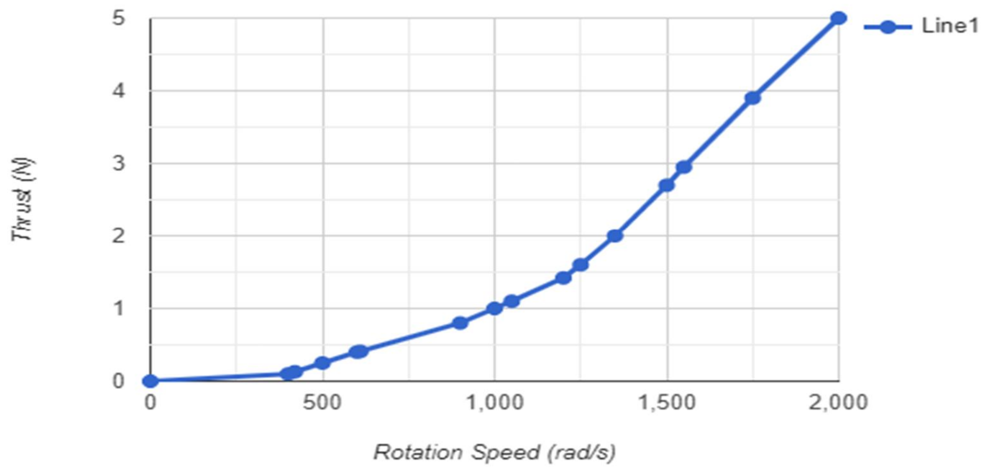
$$T = \frac{\Pi}{4} D^2 \rho v \Delta v$$

where, T= thrust (N)
D= propeller diameter (m)
v= velocity of air at the propeller (m/s)
Δv= velocity of air accelerated by propeller (m/s)
ρ= density of air (1.225 kg/m^3)

B. *Graphical Evaluation*

Thrust and rotation speed are two important factors that affect the performance of a UAV. The thrust of a UAV refers to the force that is generated by the motors and propellers to lift the UAV off the ground and keep it in the air. The rotation speed, also known as the "rpm" (revolutions per minute), refers to the speed at which the propellers are spinning. In general, increasing the rotation speed of the propellers will increase the thrust of the UAV, and decreasing the rotation speed will decrease the thrust. However, the relationship between thrust and rotation speed is not necessarily linear and may vary depending on the specific characteristics of the UAV and its propellers.

Sr. No	Thrust (N)	Rotation Speed (rad/s)
1.	0	0
2.	0.1	400
3.	0.13	420
4.	0.25	500
5.	0.4	600
6.	0.41	610
7.	0.8	900
8.	1	1000
9.	1.1	1050
10.	1.42	1200
11.	1.6	1250
12.	2	1350
13.	2.7	1500
14.	2.95	1550
15.	3.9	1750
16.	5	2000



IV. CONCLUSION

The importances of UAVs in firefighting operations is discussed in this research. The UAV will be made to have a maximum load capacity of 4 kilograms and a battery life of 25 to 30 minutes, lowering the risk to the firefighters. A thermal imaging camera, which is used to find people trapped in buildings during fire accidents, can be added to UAVs. In order to streamline industrial processes, increase their utility, and become extensively used in a variety of future industries, UAVs must develop intelligence and rapid thinking. These criteria can apply to engineering, maintenance, critical infrastructure management, and asset management operations if more attention is placed on them. Indian businesses are attempting to integrate this cutting-edge technology into their systems to make their operations safer, more dependable, and more predictable. Implementing this technology in the automotive industry can be excellent from an industrial standpoint.

In conclusion, the fire extinguishing UAVs project Illustrated the potential for using UAVs as an effective tool for fire extinguishing. The design and development of the fire extinguishing UAV have resulted in a device that is capable of quickly and safely accessing difficult-to-reach areas, delivering fire-extinguishing agents, and reducing the risk to human firefighters. The testing and demonstrations conducted as part of this project have provided valuable insights into the performance and capabilities of the fire extinguishing UAV, and have shown that it is capable of effectively extinguishing small- to medium-sized fires. There are still many challenges to be addressed in the development and use of UAVs for fire suppression, such as regulatory issues, battery life, and the need for robust, reliable systems. However, the potential benefits of using UAVs in this context are clear, and further research and development in this area is necessary to fully realise their potential.

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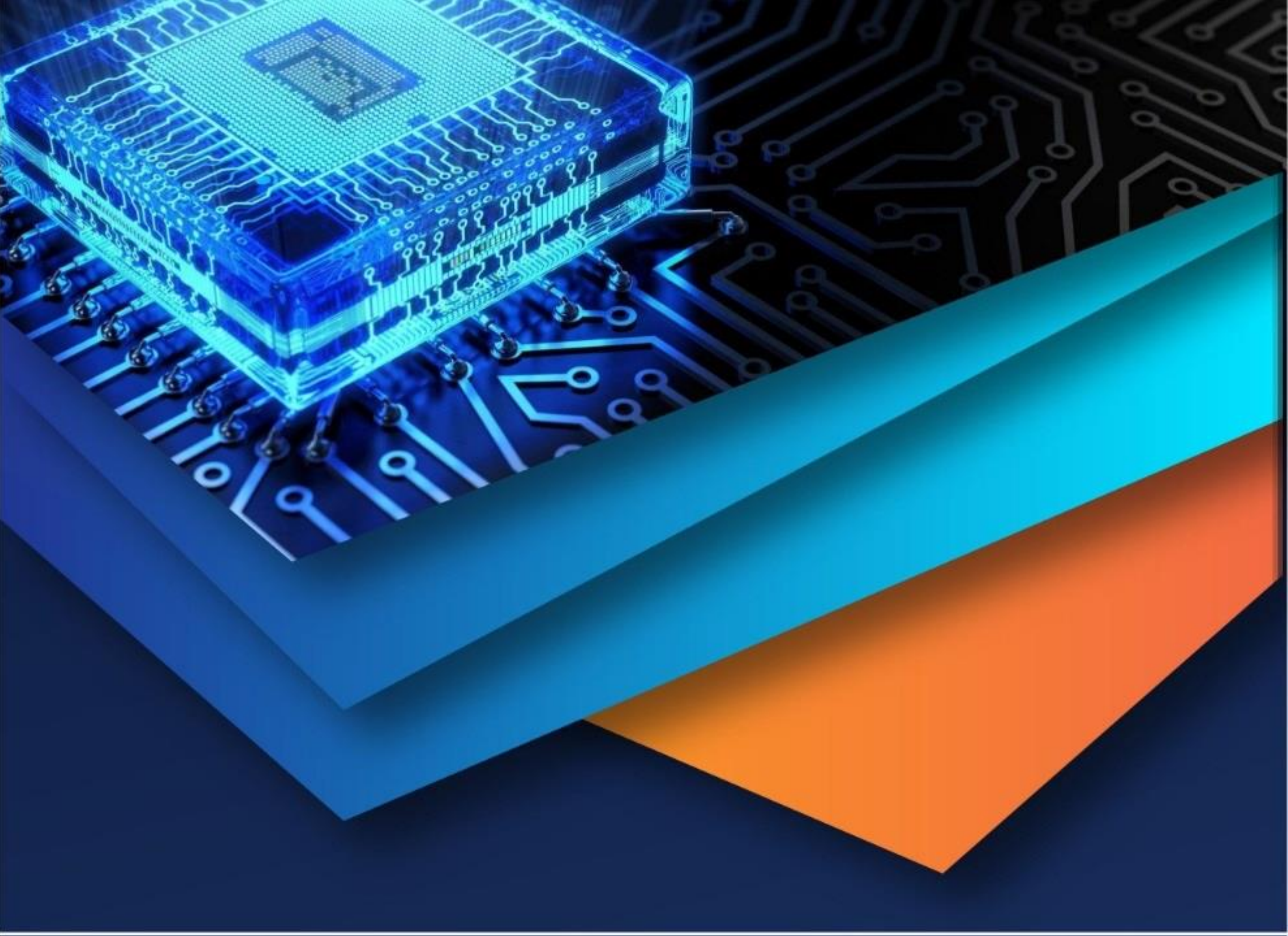

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