Review Paper: Enhancement of Efficiency and Response time of Automated Fire Fighting Drone

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Abstract: **Fires present an immense threat to humanity, causing massive and irreversible destruction. Firefighters worldwide bravely risk their lives to combat these infernos. Despite considerable technological advancements, effectively addressing fires remains challenging. The proliferation of urban areas has transformed our society into high-rise concrete jungles, often inaccessible during crises, particularly structural fires. Harnessing drone technology could revolutionize firefighting services. Our project focuses on developing a prototype firefighting drone to contain fires and minimize casualties. Drones offer versatility, allowing customization to meet specific requirements. To ensure the system's efficacy, we have outlined requirements and functionalities, designing a quadcopter equipped with an extinguishing system and a surveillance/navigation camera. This drone can be remotely controlled by firefighters, significantly reducing human involvement and the risk of physical injuries during firefighting efforts.**

Keywords: Drones, Firefighting Extinguishing system, Fire containment, Safety Equipments.

Introduction:

Globally, fires have an inevitable impact on humanity, wildlife, and vegetation, causing extensive destruction in both urban and rural areas. The inherent unpredictability of fires makes them highly perilous and life-threatening, with a small flame capable of escalating into a large-scale inferno in less than thirty seconds. In the contemporary world, firefighting primarily relies on manually operated fire equipment, necessitating the active involvement of firefighting personnel at the fire site. Firefighters put their lives on the line, facing both physical and mental risks. Developing effective methods for extinguishing fires with minimal casualties has become imperative. It is crucial to explore how technology can be harnessed to contain crises such as wildfires or structural fires while ensuring public safety.

Recently, there has been a growing focus on research in Unmanned Aerial Vehicle (UAV) systems, both in civilian and military applications. These systems are gaining attention for their capacity to operate autonomously in complex, challenging, and uncertain environments, leading to increased endurance. A UAV, or unmanned aerial vehicle, operates without an onboard human pilot. Drones have played a significant role since their inception in 1907, a decade before the first airplane was invented.

Drones, or UAVs, can either fly autonomously or be remotely piloted, offering the flexibility to carry diverse payloads based on specific requirements and applications. Multi-rotor drones, relying on multiple propellers, are a notable category in this domain. They are relatively easy to manufacture and cost-effective compared to other drone options. The number and placement of rotors on the drone can be tailored according to its intended functionality.

Despite the versatility of drone technology, there is a noteworthy contention that it remains underutilized, potentially offering remarkable advantages to emergency responders and specialists.

Capitalizing on advancements in drone technology, we can employ drones for firefighting services. Drones currently possess a superior capacity for early identification compared to the unaided eye, especially in the case of rapidly spreading fires. This project aims to leverage drone technology for fire extinguishing purposes. A quadcopter equipped with an extinguishing system is meticulously designed, taking into account the layout of requirements and functionalities. Fire personnel can control the drone from a safe distance, while the camera mounted on the drone ensures proper monitoring of the fire site. Upon identifying the target, the user can instruct the drone to spray extinguishing liquid to contain the fire. This project proves effective in suppressing small-scale fires.

Methodology:

In recent times, there has been a significant increase in reports of fire accidents, predominantly involving small-scale fires escalating into uncontrollable large-scale incidents. It is crucial to address and contain these fires at their initial stages. This project aims to achieve that objective by developing a prototype of a firefighting drone. The system must be designed to provide an effective and reliable solution while being user-friendly for fire personnel. To ensure the framework's effectiveness, a comprehensive layout of requirements and functionalities must be established.

Selecting an appropriate fire extinguishing solution is a critical requirement to extinguish the fire effectively. A thorough survey and analysis of each subsystem have been conducted to identify the most effective components and methodologies for the firefighting drone's development. After careful consideration of various options and weighing their pros and cons, a quadcopter emerged as the ideal choice for this project.

Tri-copters presented challenges in assembling hardware due to flight restrictions, and their control software was comparatively more complex than that of a quadcopter. An analysis of various fire extinguishing solutions, a conclusion was reached that a simple yet effective mixture of water, baking soda, and dish soap stands out as the most practical extinguisher among all the options.

Proposed Technique:

This project entails the implementation of a firefighting drone featuring an extinguishing system mounted on a quadcopter. The requirements are categorized into subsystems, specifically mechanical, electronics, and software. Within the mechanical system, the first requirement is the drone platform equipped with the payload and the extinguishing system. The second involves selecting the container for holding the extinguishing liquid, and thirdly, a pumping system to transfer the liquid from the container to the nozzle.

In the electronic realm, a crucial requirement is a custom-designed printed circuit board (PCB) or a power distribution board (PDB) to regulate and control the distribution of electrical power for each subsystem. The PDB and the controller collaborate to manage the on-board mechanisms and facilitate communication between multiple subsystems or devices. Additionally, there is a need for a circuit design to operate the pumping system.

The software component encompasses designing the drone platform using computer-aided design (CAD) and establishing drone controls through Mission Planner software.

System Components:

The choice of components is contingent upon the specific requirements of the project and the intended application of the drone. The selection process initiates with estimating the drone's weight according to project specifications, determining the type and size of the frame and propellers, and subsequently calculating the necessary thrust for each motor to maintain stable flight. Based on the power and current specifications of the motor, appropriate power supply and Electronic Speed Controllers (ESCs) must be selected.

When deciding on the propellers, various factors such as the number of blades, current draw, weight, and stiffness need to be taken into consideration. In the case of frame selection, parameters such as size, material, configuration, and geometry are crucial factors that need careful evaluation. The following section provides a description of the components utilized in this project.
The frame serves as the primary structure or body of the drone, providing support for all components, including hardware and payload, through the use of suitable mounting hardware. An A4-arm X-configuration is adopted for its ease of fabrication and control.

The frame is specifically tailored and designed using computer-aided design (CAD). Constructed with aluminum arms and a polycarbonate plate, it offers a rigid structure while remaining cost-effective.The motors must be chosen to provide ample thrust for the drone, ensuring stable flight with a heavy payload, such as the extinguishing system, while considering torque, speed, and KV variations. The A2212 2450KV brushless DC motors are deemed suitable for this purpose. Two sets of 1045 propeller pairs, each consisting of one clockwise-rotating and one counter-clockwise-rotating propeller with 2 x propeller shaft adapters, are utilized. These propellers control motor speed by adjusting the current based on instructions received from the flight controller, supplying the necessary 3-phase AC current to drive the motors.

For motor speed regulation, a fully programmable 30Amp BLDC ESC Circuit with 5V, 3A BEC (battery eliminating circuit) is employed. The Pixhawk 2.4.6 32bit ARM RC Flight Controller processes and coordinates instructions from other electronic components when signals are transmitted. Equipped with various sensors such as a gyroscope, magnetometer, accelerometer, etc., the flight controller senses different parameters and conditions during operation.

The selection of a battery is influenced by factors such as the number of cells, capacity, and C rating. In this project, a 3-cell, 11.1V LiPo battery with a capacity of 2200 mAh is employed. To address post-flight battery drainage, an appropriate battery charger is chosen.

The power distribution board (PDB) takes the battery voltage as input, offering multiple connection points for all other electronic components. A regulator or Battery Eliminating Circuit (BEC) is included to power low voltage components.

For communication between the ground station and the drone, a Flysky i6B 2.4GHz transceiver set is utilized. The flight controller receives signals from the transmitter or remote control through a radio receiver.

The extinguishing system comprises a mini 12V DC brushless water pump, a nozzle, and a suitable container for the extinguishing liquid. An optional FPV camera can be incorporated for surveillance and target recognition. The camera transmits signals to the Video Transmitter (VTX), and the VTX sends the signal through the antenna to a video receiver, which, in turn, transmits it to a screen.

For an FPV setup, two video antennas are typically needed for transmission and reception. A 2.4GHz transmitter and receiver are considered ideal. Alternatively, a camera module can be interfaced with a Raspberry Pi 3 B+, and the video can be streamed to the Pi's screen.

Working:

Manual control of the firefighting drone is facilitated through the radio receiver, enabling the operator to command the quadcopter's movement in various directions.

Stability is achieved by adjusting the speed of the motors and the motion of the propellers. The transmitter at the ground station, manipulated by the user, sends signals to the receiver.

Subsequently, the receiver communicates this information to the flight controller, which utilizes Electronic Speed Controllers (ESCs) to regulate motor speed, resulting in controlled movement.

The operator receives visual feedback from the quadcopter. The transmitter transmits this feedback to the receiver, which relays it to a display device, such as a screen or a base computer. This display aids the operator in navigation and decision-making regarding the target location, specifically the location of the fire.

The extinguishing liquid consists of a solution of baking soda, detergent or dish soap, and water. The pump within the extinguishing container is connected to a power supply and a controller to enable automation. The controller interfaces with a receiver, and the transmitter connects to a controller and a switch under the operator's control. The switch regulates the on-off function of the pump for the purpose of spraying.

Design and Implementation:

The initial phase in constructing a drone involves deciding on its configuration and assembling various frame components, such as the landing gear and mounting plate, using screws and nuts. After determining the suitable positions and orientations for all components, the Power Distribution Board (PDB) is affixed. Before mounting, the battery connector and other small pads are soldered to the PDB. Subsequently, the motors are securely fastened according to their designated positions.

As there are two sets of clockwise and anticlockwise motors, opposite motors within the X configuration must spin in the same direction. After positioning the motors, the four Electronic Speed Controllers (ESCs) are affixed to the arms of the frame using double-sided tape. Each motor possesses three wires that will be connected to the ESC with a bullet connector.

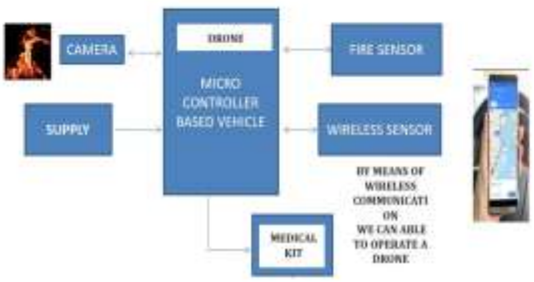

Fig.3.1 Block diagram of Fire Fighting Drone

The next step involves connecting the other end of the Electronic Speed Controller (ESC), which has a positive and negative wire, to the respective pads on the Power Distribution Board (PDB). With the power system now ready, the setup of the First Person View (FPV) system can proceed by powering the camera and Video Transmitter (VTX) from the PDB. Alternatively, a Raspberry Pi can be utilized to interface with the camera and stream video on its screen. It's worth noting that the use of the camera is optional since the primary goal of this project is to extinguish small-scale fires.

Moving on to the wiring of the flight controller, it requires 5V power supplied by the power module, which also enables the Pixhawk to monitor the current and voltage levels of the main battery. The power module has a 6-pin cable plugged into the power port of the flight controller. The signal wire and signal ground wire from each ESC are connected to the flight controller, with output connections to the motors arranged according to their specified order. Additionally, a safety switch and a buzzer must be connected to the Pixhawk flight controller in their designated ports.

The receiver is then mounted and powered, receiving power from the flight controller. The signal wire in the receiver is connected to either a UART RX based on the mode of communication. Pixhawk is compatible with a PPM-Sum receiver, so the ground, power, and signal wires are plugged into the RC pins on the flight controller (Pixhawk). Completing the setup involves binding the transmitter and receiver. The battery can be connected through the power module as needed.

For the extinguishing system, an electronic submersible pump, along with a bent pipe for improved efficiency, is placed inside a suitable container. A nozzle is connected at the container's mouth for spraying the extinguishing liquid. Switch A on the transmitter is programmed to control the on-off function of the pump. Specifically, switch A is assigned to channel 5 on the receiver. The flight controller receives information from this channel through the receiver, and output pin 5 is connected to the pump. This setup allows the user to control the pumping action from the ground station, completing the hardware implementation of the project.

Software Implementation:

The Mission Planner software, an essential ground station application provided for drone pilots, facilitates the configuration of various drone aspects. Calibration and setup of the drone are conducted through this software. After installing the software on a PC, establish a connection between the drone and the PC using a USB cable. Subsequently, peripheral setup is required, involving the configuration of the drone by selecting the frame layout, calibrating various components, and setting up flight modes.

For optimal drone performance, assumptions about the aggregate weight of the quadcopter are made to determine the appropriate frame size, propeller size, and the thrust generated by the motors to lift and maintain stable flight. In this instance, the selected motors are designed to provide an approximate thrust of 800g each. Specific parameters such as the angle between the frame surface and the landing gear (-50 degrees), the height of the landing gear (4.5 inches), and the width of the landing gear (0.2 inches) are considered during the configuration process.

Top of Form

- Quadcopterflighttime=(batterycapacity*batterydischarge/averageAmpdraw) *60
- Battery capacity= 2200mAh
- Battery discharge=80%
- Avg amp draw=20A
- Quadcopter Flight time = ([(2200/1000)*(80/100)] /20)*60
- Quadcopter Flighttime = 5.28minutes

Results and discussion:

Through extensive research, design modeling, and multiple testing techniques, a meticulous selection process was employed to meet all the specified requirements for developing and constructing an efficient system. Initially, calibration challenges were encountered, but after two attempts, successful calibration was achieved. The quadcopter, equipped with the extinguishing system, demonstrated the ability to fly and hover over a location illuminated with fire. It is crucial to exercise caution when setting up the fire.

In the initial attempts, a challenge emerged as the drone unintentionally contributed to the fire's escalation due to downward thrust. This issue was attributed to the arrangement of the extinguishing bottle, with its nozzle facing vertically downward. To address this problem, corrective measures were taken by placing the nozzle horizontally at an angle and bending the nozzle pipe.

In summary, the design and development of a firefighting drone, capable of extinguishing small-scale fires, have been successfully executed. For experimental purposes and unforeseen circumstances during test flights, the project was also conducted using a pre-made drone frame.

Conclusion:

Fire, an age-old destructive force, has become more manageable with technological advancements. This paper presents a solution to firefighting challenges using drone technology and a specialized extinguishing system. It outlines and illustrates the construction process for a drone capable of extinguishing small-scale fires. In conclusion, leveraging continually evolving drone technology offers a safer approach to firefighting, reducing firefighter involvement and minimizing the risks of physical injuries and life-threatening situations. Comparing this prototype with the current technology employed by fire departments, which predominantly uses drones for surveillance purposes only, highlights the efficiency of this project.

One notable advantage of drones lies in their dynamic payloads, allowing for multiple equipment configurations based on user requirements. With adequate funding, further development of this prototype could involve the incorporation of thermal imaging and GPS modules, enabling autonomous fire detection and navigation through flames, eliminating the need for human control.

Expansion possibilities include integrating multiple drones through Flying Ad-Hoc Networks, forming an interconnected drone network or a swarm. This approach could address large-scale structural fires and wildfires, providing enhanced monitoring and firefighting coverage. Another potential enhancement involves using a high-grade extinguishing fuel, equipping the drone with a fire extinguishing bomb that outperforms many existing firefighting techniques when deployed into the fire. Utilizing such innovative solutions can alleviate the pressure on the drone and enhance firefighting effectiveness.

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