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Drone-Based Elevated Mirror Cleaning System with Real-Time Video Streaming

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Abstract: *Nowadays building maintenance is not easy to handle. In building maintenance there is a huge rolling glass maintaining, especially in high –rise building, those things are still maintaining by manpower. To achieve high quality result for that kind of cleaning, the maintenance group and others must give high contribution Effect. To get effective output, have to get the secondary data from reputed websites hence it will lead to the false results project output, after gathering those things, have to simulate that obtained data. In this design project simulation part will be the most important part to consider. The whole project's output will be depended on the simulation results. Analyzing those result to get the possible positive output. To get appropriate solution has to design a new system based on analytical data.*
Design process is going under international regulations and frameworks; therefore that effective output will be safe and solving following problem and improving maintenance of the high rise- building glasses. To test the given solution, also have to simulate the final design and must prove with the evidence, that the new cleaning system will increase the maintainability of that kind of high –rise building glasses.
Keywords: Drone, mists praying system, wiper mechanism, Wi-Fi-enabledESP32camera, architecture of drone

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I. INTRODUCTION

This project focuses on the design and development of an innovative autonomous cleaning drone equipped with advanced features to address modern challenges in cleaning, agriculture, and environmental monitoring. The drone incorporates a cleaning roller driven by a DC motor to effectively clean surfaces, making it ideal for maintenance tasks in various environments.

Four BLDC motors provide stable and efficient flight, enabling the drone to navigate diverse terrains with precision. The integration of a mist spraying system further enhances its functionality.

A significant highlight of this drone is its Wi-Fi-enabled ESP32 camera, which provides real-time video streaming capabilities. This feature allows users to remotely monitor and control the drone, ensuring high operational efficiency and safety.

The video feed can be accessed via any Wi-Fi-compatible device, making it easy to oversee cleaning or spraying tasks from a distance. Additionally, the system includes a mist sensor that optimizes the spraying process by adjusting the mist output based on environmental conditions, reducing resource wastage and improving precision.

The autonomous cleaning drone has wide-ranging applications across industries. In cleaning and maintenance, it can clean large or hard-to-reach surfaces, such as building exteriors, industrial equipment, or solar panels. In agriculture, the drone can be used for targeted spraying, reducing manual labor and enhancing crop care.

Environmental monitoring is another area where the drone can contribute, particularly in tasks like dust suppression or maintaining air quality. The combination of innovative features and versatility makes this drone a promising solution for modern industrial and environmental challenges.

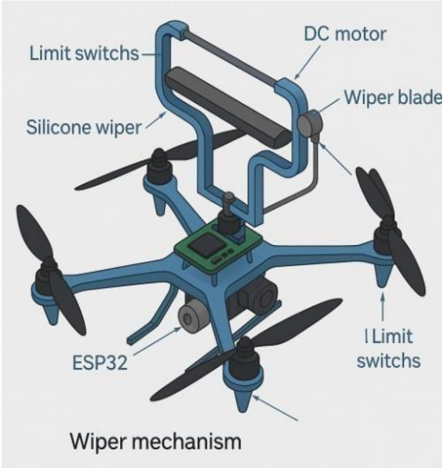


Fig1.1: Drone Components

DRONESYSTEMOVERVIEWANDSPECIFICATIONS

i. CATEGORIESOF DRONE
ii. FRAMECONFIGURATION
iii. PAYLOADS
iv. DISTANT FACTORSANDCONFIGURATIONS
v. DIFFERENTCOMPONENTS MOTORS
PROPELLERS BATTERY
ARMS etc.
vi. BASEDONFC(FLIGHTCONTROLLERS)
vii. ARCHITUREOFDRONE

II. LITERATUREREVIEW

Design and Development of Unmanned Aerial Vehicle (Drone) for Different applications. The modern designs and their developments are essential based on their application; hence, UAV's can be built with specific design and loading conditions. In this review for the first, a basic idea about UAVs considering required engineering aspects has been studied. The existing literature has been critically reviewed to extract the fundamental idea of UAVs such as fabrication method, design, materials, structures, classifications and so on.

The author *Abdul Aabid*[1], and co, reviewed on Design and Development of Unmanned Aerial Vehicle (Drone) for Different applications in their research, a basic idea about UAVs considering required engineering aspects has been studied. The existing literature has been critically reviewed to extract the fundamental idea of UAVs such as fabrication method, design, materials, structures, classifications and so on. The UAVs in multiple applications such as the use of drones by law enforcement agencies, military, search, and rescue missions, etc.

The author *Luis Miguel González de Santos*[1]and co., done their research on Drone Spraying Application for the Disinfection of Surfaces against the COVID-19 Pandemic, and the study explored the use of Unmanned Aircraft Systems (UAS) for performing disinfection tasks in various open environments.

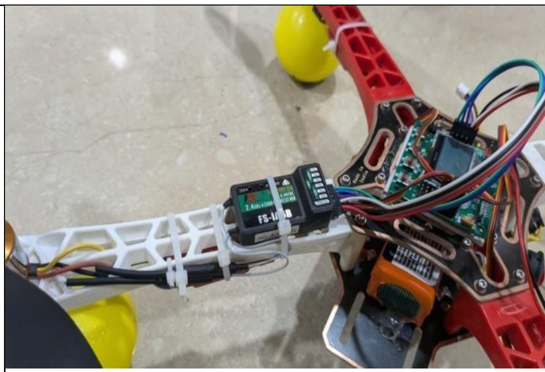
The author *S.Rehman*[1]andteam explores the study on Cleaning of photovoltaic panels utilizing the downward thrust of a drone. The study confirms that drone-based cleaning is an effective, contactless, and practical method for maintaining PV panel efficiency in dust-prone environments like Saudi Arabia.

III. DESIGN & DEVELOPMENT OF DRONE

The drone's frame is engineered to provide a balance between strength, lightweight construction, and aerodynamic efficiency, which is essential for stable flight and longer operation times. Material selection is crucial, with options like carbon fiber or reinforced composites ensuring durability while keeping the overall weight minimal for optimal flight dynamics.

The frame includes specific mounting positions for BLDC motors at the ends of each arm, a central hub for placing the flight controller and battery, and allocated areas for the cleaning roller, mist spraying system, and ESP32 Wi-Fi camera. A modular construction approach is used, allowing for easy assembly, upgrades, and maintenance, where individual components like motors, the mist tank, or cleaning systems can be replaced without disassembling the entire frame. Aerodynamic performance is enhanced by streamlining the frame's structure and ensuring that protruding elements like mist nozzles and cameras are integrated smoothly within the airflow path to minimize drag.

Vibration damping is achieved using strategically placed rubber mounts and braces, effectively isolating sensitive electronics from motor-induced vibrations and ensuring accurate sensor data and system stability. Weight distribution is carefully planned, positioning heavier parts such as the battery centrally to maintain a stable center of gravity, which is critical for precise movements and balanced flight performance.

	
Fig3.1:Drone view-1	Fig3.2:Drone view-2

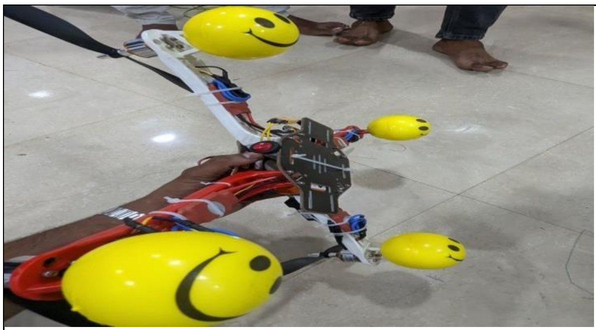
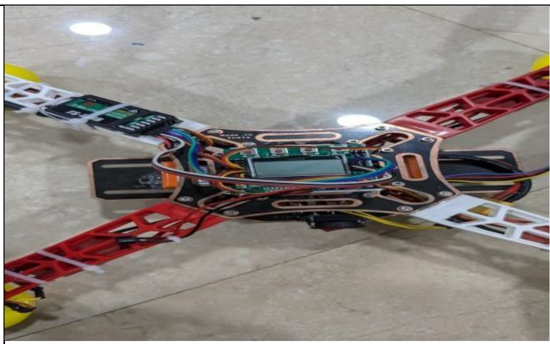
	

Fig3.3:Drone view-3	Fig3.4:Drone view-4

WIPERMECHANISM

A wiper mechanism is a motor-driven system designed to move a wiper blade back and forth across a surface to remove dust, water, or debris. When integrated into drones, it helps clean surfaces like solar panels, glass facades, or industrial equipment remotely.

Mini DC Geared Motor (60–200RPM)—for back-and-forth wiper movement. Wiper Arm (lightweight acrylic/ABS rod) — connected to the motor shaft.

Flexible Silicone Wiper Blade —fixed to the arm for smooth surface cleaning. Limit Switches (2units)—to detect end positions and reverse motor direction.

Motor Driver (L298N/L9110)—to control the DC motor via microcontroller..Micro controller (ESP32/Arduino Nano)

—already present in your system

Fig3.5: WIPER MECHANISM

ARMS: ABS (Acrylonitrile Butadiene Styrene) MATERIAL

The use of ABS in the drone's arms provides exceptional resistance to accidental impacts or collisions during flight or landing. This ensures that the drone remains operational even after rough encounters with obstacles, reducing the risk of damage

Lightweight: ABS provides an optimal weight-to-strength ratio, crucial for flight performance.
Durability: Resistant to impact, ensuring the drone's longevity even in rugged conditions.
Temperature Resistance: AB Scan with stand a wide range of temperatures, maintaining stability in different climates.
Easy Molding: Allows for precise manufacturing and easy customization of arm designs.
Visuals: Diagram or image showing the ABS material composition with arrows pointing to drone arms, indicating flexibility and strength.

Manufacturing Process of ABS Drone Arms

The drone arms are molded using ABS thermoplastic, which allows for precise and efficient production. The injection molding process ensures that each arm is structurally sound and uniform, reducing production time and cost.

Steps Involved

Injection Molding: ABS material is heated and injected in to molds for precision shaping. Post-Processing: After molding, the arms are treated for additional strength and finish.

BLDC MOTORS

The autonomous cleaning drone uses four high-performance BLDC (Brushless DC) motors as its primary propulsion system for stable and agile flight. BLDC motors are favored in drones for their high torque-to-weight ratio, efficient power usage, and low maintenance needs. Each motor is mounted at the end of the drone's arms, providing balanced lift and directional control for smooth aerial maneuvers. The brushless design minimizes mechanical wear, enhancing durability and extending operational lifespan. These motors can rapidly adjust their rotational speeds, allowing quick responses to environmental changes like wind or directional shifts. Paired with Electronic Speed Controllers (ESCs), the motors offer independent control over pitch, roll, yaw, and altitude for precise positioning. BLDC motors support a wide range of propeller types, enabling operational flexibility based on specific cleaning or spraying tasks. Their low electromagnetic interference ensures reliable functioning of onboard electronics, including the drone's Wi-Fi camera and mist sensors.

Fig3.6: BLDC Motor

Fig3.7: BLDC Motor with drone

CLEANINGROLLERMECHANISM

The cleaning roller is a rotating mechanism mounted underneath the drone for contact-based surface cleaning applications. It features a light weight, durable brush or microfiber material optimized for removing dust, stains, and light debris. The roller is powered by a dedicated BLDC motor, providing adjustable speed based on surface type and cleaning intensity. Its design includes a flexible mounting system that allows it to maintain consistent contact with uneven surfaces. The roller's operation is synchronized with the drone's flight and mist spraying system for efficient multi- tasking. An integrated feedback system monitors roller performance, detecting wear, jamming, or obstructions in real- time. The mechanism can be easily detached and replaced for maintenance or material changes depending on cleaning requirements. It significantly enhances the drone's versatility in cleaning industrial facades, glass structures, or high- altitude installations.

MISTSPRAYINGSYSTEM

The autonomous cleaning drone features an integrated mists praying system that enhances its use in agriculture, industry, and environmental management. The system includes a fluid reservoir, high-efficiency pump, mist nozzles, and a mist sensor for real-time control of spray output. Its primary role is to distribute fine water or chemical mist for applications like crop spraying, pest control, humidification, and dust suppression.

Lightweight construction ensures the mist system has minimal impact on the drone's flight stability and agility. Mist is produced by atomizing liquid through precision nozzles, ensuring even and consistent coverage a cross target areas. A high-pressure pump and onboard control system enable operators to adjust mist intensity and flow rate based on specificneeds.Themistsensorcontinuouslymonitorsmistdensityandatmosphericconditions, allowing automatic optimization of spray output and reducing resource wastage. Compatible with various liquids and synchronized with the drone's navigation sensors, the system ensures precise, efficient, and environmentally responsible spraying in any terrain.

Fig3.8: Mist spraying system

ESP32WI-FICAMERA

The drone features an ESP32 Wi-Fi-enabled camera that provides real-time video streaming for operational control, monitoring, and safety. This lightweight, compact, and energy-efficient camera is ideal for aerial applications where weight and power consumption are critical. It streams live video via Wi-Fi to smart phones, tablets, or computers, allowing operators to monitor tasks like cleaning, spraying, and inspection remotely.

The camera offers high-resolution, detailed visuals of the work environment, ensuring thorough coverage and accurate operations. It can be programmed for automated tasks such as area surveillance, inspection of hard-to-reach spots, or identifying areas needing focused attention. The system supports remote camera angle adjustments, zoom, and image capture, improving versatility for various operational scenarios. Low-latency, interference-free video streaming ensures near-instant feedback for real-time adjustments and quick decision-making during flight. Housed in a protective casing against dust, moisture, and impact, the ESP32 camera also aids in navigation, obstacle detection, and task documentation, making it a vital multifunctional component.

POWERSUPPLYANDBATTERY

The power supply and battery management system (BMS) provide the energy required for flight and task execution.

The drone uses high-capacity lithium-polymer (LiPo) batteries, ideal for aerial applications due to their lightweight and high energy density. The BMS ensures battery safety by monitoring voltage, temperature, and charge cycles, preventing overcharging or deep discharge. Real-time data on battery health and state of charge (SoC) allows operators to manage power efficiently and plan recharging. The flight control system optimizes power usage based on task demands, prioritizing battery life when performing low-energy activities. The power supply incorporates energy-efficient components to extend flight duration, reducing energy consumption. The battery is designed for easy removal and replacement, enabling quick turnaround for prolonged operations. A robust BMS ensures the drone operates at peak efficiency, safeguarding against electrical faults and performance degradation.

PROPELLER

Size Specification: The propeller measures 10 inches in diameter and has a 4.5-inch pitch, meaning it moves forward 4.5 inch espier full rotation through the air. Balanced for Medium-Load Drones: Ideal for drones carrying additional payloads like cleaning rollers, mist spraying systems, and cameras-providing sufficient lift without overloading the motors. Compatible with 800–1000KV Motors: Pairs well with BLDC motors rated around 800–1000KV, which are commonly used for stable and efficient flight operations. Works with 30A ESCs: The propeller's size and thrust output match perfectly with 30A ESCs, allowing for smooth speed control and handling of extra current during takeoff or cleaning tasks. Enhanced Lift Capacity: A 10-inch diameter provides a broader air displacement, generating higher lift— essential when carrying the added weight of mist tanks and cleaning equipment. Material Options: Available in carbon fiber, reinforced plastic, or nylon composite — carbon fiber recommended for high-durability, lightweight, and better vibration absorption.

FC (FLIGHTCONTROLLER)

1. Core Operational Unit: The Flight Control System (FCS) is the central system responsible for managing the autonomous cleaning drone's flight stability, navigation, and task execution by integrating both hardware and software components.
2. Multi-Sensor Integration: The FCS collects continuous data from sensors such as accelerometers, gyroscopes, barometers, and GPS, providing real-time monitoring of the drone's orientation, altitude, speed, and geographic position.
3. Flight Stability Control: Using accelerometers and gyroscopes, the FCS detects pitch, roll, and yaw movements, adjusting motor speeds to stabilize the drone against disturbances like wind or sudden changes in direction.
4. Altitude and Position Management: Barometers help measure precise altitude, essential for mist spraying and roller cleaning tasks, while GPS ensures accurate positional awareness for waypoint navigation, area mapping, and return-to- home (RTH) features.
5. Advanced Control Algorithms: The FCS processes sensor data through algorithms like PID (Proportional-Integral- Derivative) control to fine-tune throttle, pitch, roll, and yaw by adjusting ESC outputs, ensuring smooth, balanced flight.
6. Coordination with On board Systems: The FCS communicates with other drone systems —including the mist spraying unit, cleaning roller, and Wi-Fi camera — ensuring synchronized task execution and operational efficiency.

ESC (ELECTRONICSPEEDCONTROLLER)

High-performance BLDC motors for stable flight will likely draw between 20A to 30A continuous current, especially under load when the cleaning roller is active and mist spraying adds weight. A 30A ESC ensures safe, reliable motor control without overheating or voltage drops during mist spraying or surface cleaning. Capable of handling sudden current spikes (35A-40A burst) during sharp man oeuvres, wind resistance, or rapid acceleration. Compatible with ESP32 or flight controllers via standard PWM signals. Compact and lightweight — essential for maintaining drone flight efficiency. Precisely controls motor speed based on signals from the flight controller. Maintains flight stability when the drone encounters extra load from mist spraying or cleaning.

RECEIVER

SimonK 30A is an Electronic Speed Controller (ESC) designed to regulate and control the speed of BLDC (Brushless DC) motors in drones and RC models. Flashed with SimonK firmware, it offers fast, smooth, and precise motor response, making it ideal for multi rotor drones that require quick and stable flight adjustments. Supports high-frequency signal inputs (up to 600Hz), reducing input lag between the flight controller and motor, which enhances flight stability and maneuverability. Rated for continuous current up to 30 Amps, making it suitable for medium-sized drones like your autonomous cleaning drone with four BLDC motors. Equipped with a built-in Battery Eliminator Circuit (BEC) that provides a stable 5V output to power the flight controller or receiver. Connects directly to the drone's flight controller via signal wire and to the BLDC motor via three-phase output wires, converting battery DC power into three-phase AC power for motor operation. Known for its simple configuration and reliable performance, especially under sudden throttle changes and rapid speed adjustments in aerial applications.

TRANSMITTER

Operates on 2.4 GHz AFHDS 2A protocol, providing reliable, interference-resistant communication for drones and RC models. Features 6 configurable channels, suitable for controlling essential drone functions like throttle, yaw, pitch, roll, mist spraying, and cleaning roller operation. Ergonomic design with an LCD display for easy navigation of settings, Telemetry data and real-time adjustments. Telemetry support when paired with compatible receivers like FS-iA6B, allowing real-time monitoring of parameters like battery voltage and signal strength. Customizable controls with servo reversing, dual rates, endpoint adjustments, and expo settings for precise flight control and operational flexibility. Control range of approximately 500–1000 meters in open areas, making it ideal for agricultural and industrial drone operations over large surfaces. Easy pairing and binding process with receivers, ensuring quick setup and reliable communication link with the drone's flight controller. Budget-friendly, reliable, and widely used in DIY, educational, and industrial drone projects due to its versatility and proven field performance.

SATEFYANDFAILSAFEMETHOD

The drone is equipped with GPS-based return-to-home functionality, enabling it to autonomously return to its launch point during emergencies. A fail-safe system monitors battery levels and triggers an autolanding procedure if critical power levels are detected. Obstacle detection sensors continuously scan the surroundings and trigger evasive maneuvers to avoid collisions. The flight control system includes redundancy protocols, maintaining operational control in the event of single-point failures. Emergency landing protocols can be activated remotely by the operator in case of unpredictable hazards. The protective housing for onboard electronics shields components from dust, moisture, and mechanical impact. The autonomous system halts operations automatically if communication with the ground station is lost for a preset duration. Built-in visual and audio warning systems alert nearby personnel during drone operation to enhance operational safety.

IV. APPLICATIONS AND FUTURE SCOPE

1. The drone is ideal for cleaning high-rise building facades, solar panels, industrial warehouses, and public structures.
2. It can be deployed in agriculture for pesticide and fertilizer spraying, reducing labor costs and health risks.
3. Environmental agencies can use the drone for air quality monitoring, dust suppression, and water body maintenance.
4. Industrial sectors can deploy it for inspection and maintenance of hard-to-reach equipment or hazardous sites.
5. Future iterations may integrate AI-based image analysis for automatic detection of dirty areas, cracks, or structural damage.
6. Expansionintoprecisionagriculturecouldincludeplanthealthmonitoring, soil moisture mapping, and targeted nutrient delivery.
7. Advanced environmental drones could assist in disaster management by delivering disinfectants or monitoring air toxicity.
8. Ongoing improvements in battery life, payload capacity, and AI-powered navigation will further expand its operational capabilities.

V. CONCLUSION

1. The development of a drone-based elevated mirror cleaning system integrated with live streaming marks a significant step forward in the maintenance of high-altitude and hard-to-reach reflective surfaces.
2. By combining aerial mobility with real-time monitoring, the system offers a safer, more efficient and cost-effective alternative to traditional manual cleaning methods.
3. The drone's ability to access elevated mirrors, coupled with its onboard cleaning mechanism and live video feedback, ensures both operational precision and user confidence.

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