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Pov Display Drone

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Abstract- This review paper explores the creation of an entertainment drone powered by a KK microcontroller, which includes a rotating LED display for dynamic visual effects and advertising purposes using an Esp32 microcontroller. The goal was to develop an affordable, adaptable, and programmable aerial platform that integrates stable flight control with captivating visual displays. The ESP32 is noted for its dual-core processor, built-in Wi-Fi and Bluetooth, and robust multitasking abilities, making it ideal for managing LED display tasks. KK is a common microcontroller used for drone integration. This paper covers the entire design process, from component selection to the integration of hardware and software. It also reviews existing point-of-view (POV) display drones and describes how the persistence of vision is employed to create midair visuals such as text, images, and animations. The drone can be controlled via remote, offering convenience and flexibility of the method The review addresses key challenges such as power management, display synchronization, flight stability, and the role of IoT in enhancing system performance. Practical applications, including light shows, advertising, and educational demonstrations are also discussed. Despite challenges like payload limitations and time sync, the review demonstrates that combining entertainment technology Embedded systems can offer economical and scalable solutions.

Keywords: Entertainment Drone, POV LED Display, ESP32, and IOT etc.

I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), also known as drones, have rapidly evolved and are used across a wide range of industries. Today, they play vital roles in surveillance, precision agriculture, aerial photography, filmmaking, environmental monitoring, and even everyday recreational activities. As advance technology continues to integrate, drones are becoming increasingly capable of performing complex tasks such as wireless communication, real- time image processing, environmental sensing, and producing sophisticated LED-based visual effects—all while maintaining compactness, efficiency, and affordability. In recent years, drones have emerged powerful in the entertainment industry: drone light shows. These performances have transformed audiences experience events, festivals, and celebrations by painting the night sky withcoordinated, vibrant animations. Traditionally, such shows rely on large fleets of drones working together to create patterns and imagery [17]. However, this approach can be expensive and logistically demanding. The drone project explores a more innovative and cost-effective alternative by developing a single entertainment drone capable of producing dynamic visuals through a Persistence of Vision (POV) display. The drone incorporates a rotating LED setup that leverages the POV effect, where rapidly moving LEDs blend into smooth, continuous images as perceived by the human eye [37]. By precisely synchronizing LED illumination with the rotation speed, the system can generate stable animations, symbols, or scrolling text that appear to float in the air as the drone hovers. Overall, the project demonstrates how two technologies integrated together can make advance technology, offering a practical, creative, and economical solution for modern entertainment applications.[20]

II. LITERATURE REVIEW

Recent literature on unmanned aerial vehicles (UAVs) shows a growing interest in combining lightweight embedded systems with innovative visual-display payloads to expand the functional capability of drones. In UAV research, projects such as YOLO-

Drone by Zhu et al. (2023) demonstrate how drones can reliably execute real-time tasks, even dense small-object detection at high altitudes, by integrating efficient onboard processing and LED-assisted illumination. Meanwhile, a separate body of work has advanced the design and control of persistence-of-vision (POV) LED displays, which create images by rapidly spinning LED arrays to exploit the human visual system's fusion threshold. For example, the Persistence of Vision Display prototype by Mishra, Sharma, Bharadwaj, and Aggarwal (2021) [27] illustrates how clear two-dimensional images can be rendered using only a small number of LEDs, provided that rotational speed, timing precision, and synchronization sensors are carefully managed.

Complementary to this, recent maker- and research-oriented implementations such as Joseph's 2024 "POV Display Using ESP32" project highlight the suitability of the ESP32 microcontroller for POV systems because of its dual-core architecture, integrated wireless communication, high- frequency PWM outputs, and capacity for real-time updates. When considered together, these works suggest that an ESP32- controlled POV display is a strong candidate for drone-mounted visual communication, as it offers low weight, low power consumption, wireless programmability, and sufficient computational bandwidth for dynamic image rendering. [29] However, existing literature treats UAVs and POV displays largely as independent domains—UAV studies focus on sensing, autonomy, and navigation, while POV work focuses on LED timing, rotational mechanics, and visual quality.

Only limited research explores their integration, leaving challenges such as vibration-induced frame distortion, energy budgeting during flight, wireless content stability, and mechanical balancing unresolved. This gap presents an opportunity for new research that merges UAV mobility with ESP32-driven POV image generation, potentially enabling applications such as aerial signage, real-time environmental alerts, and coordinated multi-drone display systems. Again, an POV Led display system by Circuit Digest display how multiple led syncs together and form stable image. Even commercial company like Fly in Diamond and Intel have also shown interest in drone light show, drone entertainment industry.[34] [17]

III. METHODOLOGY

This section describes the development of two integrated subsystems:

- the quadcopter platform used for aerial operation, and
- the detachable POV LED display module mounted underneath the drone and controlled independently using an ESP32 microcontroller. Both subsystems are to be designed so that flight control and visual display functions operate in parallel without interfering with one another.

A. Drone Setup: -

- Frame and Controller Installation: X shape frame will be selected as drone frame for even weight distribution and reduce vibrations. The flight controller is to be positioned at the centre and isolated using soft mounts to reduce the impact of motor vibration on sensor accuracy.
- Propulsion System Assembly: Each arm is to be fitted with a brushless motor, following the standard quadcopter rotation scheme with alternating CW and CCW directions. Matching propellers to be installed accordingly, to maintain torque balance.[23]
- ESC and Power Wiring: The ESCs to be wired to the power distribution board and connected to the flight controller via motor output pins. An XT60 interface connects the 3S Li-Po battery to the distribution board, supplying power to the components.
- Receiver Integration: The Fly Sky FS-i6 receiver is to be connected to the flight controller using channel. The controller is configured for throttle, roll, pitch, yaw, and auxiliary switches.[19]
- Payload Mounting: A lightweight mounting bracket is installed at the bottom of the frame to hold the POV display module. The bracket ensured that the additional mass did not obstruct airflow or alter the drone's centre of gravity significantly.[12]

- Controller Calibration: The flight controller firmware was configured through its setup interface, including accelerometer and gyroscope calibration, ESC throttle range calibration, and radio channel calibration.
- Flight Mode Setup: Self-level (angle) mode should be enabled for stable beginner flights. Optional modes such as acro/manual were configured for later testing once stable payload flight are to be achieved.[22]

B. POV LED Display System

1) Hardware Integration The POV module consists of a high-density LED light mounted at the bottom of the quadcopter, driven by an ESP32 microcontroller. A lightweight mounting bracket is to be fabricated to reduce vibration transfer. The ESP32, powered via a regulated 5 V supply from the drone's battery, operates independently of the KK controller to avoid interference.[33]

Key components include:

- ESP32 development board
- LED Source (3mm Round LED)
- Battery
- Lightweight mounting arm
- Protective casing to prevent airflow disturbance

2) POV Hardware–Software Operation The POV system employs an integrated hardware–software workflow: The ESP32 receives image or text data over Wi- Fi through a browser-based control interface hosted on its internal webserver. A custom firmware, developed using the Arduino framework, converts incoming data into pixel- mapped LED patterns. The LED source is updated synchronously with drone rotation speed so that persistence of vision produces a complete visual frame during flight. Real-time adjustments (brightness, pattern selection, rotation compensation) can be performed remotely via the web interface.[37]

The software includes:

- Wi-Fi Access Point (AP) mode configuration
- HTTP server for image/text pattern upload
- LED-driving algorithms optimized for rotation-based display.
- Timing compensation algorithms based on IMU feedback if required.

C. Testing and Evaluation The POV system to be evaluated under various lighting and rotational conditions, to measure display clarity, pattern stability, and frame completeness.

Tests include:

- Static ground rotation tests
- Controlled low-altitude hover tests
- Night-time visibility evaluation
- Latency and reliability testing of Wi-Fi control
- Power consumption and thermal characteristics are to be monitored to ensure safe operation during extended flights.[25]

IV. SYSTEM WORKFLOW

The complete system operates through a series of coordinated stages that bring together the quadcopter platform and the ESP32-based POV LED display. These stages—system initialization, communication and control setup, flight operation, and POV visualization—ensure that both subsystems function smoothly without interfering with one another.

A. System Initialization-

1) Power-Up Sequence: When the Li-Po battery is connected, both the KK flight controller and the ESP32 start up independently. The KK controller automatically begins its usual calibration routine, which includes stabilizing the accelerometer, gyroscope, and synchronizing all ESCs. At the same time, the ESP32 sets up its Wi-Fi access point and activates the LED control circuitry.[50]

2) Hardware Diagnostics: Before any operation, the quadcopter checks motor–ESC connections, verifies receiver inputs, and confirms PID readiness.[40] Parallel to this, the ESP32 has to run a quick check on the LED strip and verifies that stored display patterns can be accessed correctly.

3) Subsystem Isolation: To avoid electrical noise affecting flight stability, the system verifies that the flight controller and POV electronics remain electrically isolated. This will ensure clean IMU readings and reliable LED performance.[24]

B. Communication and Control Setup

1) Radio Link Establishment: The Fly Sky FS-i6 transmitter and receiver pair form a dedicated control link with the KK controller, giving the operator full manual control of the drone.

2) Wi-Fi Webserver Configuration: The ESP32 initializes an onboard webserver. Users can connect through a smartphone or laptop to upload text, images, or choose from stored POV patterns.[15]

3) Data Processing: The ESP32 converts the uploaded content into display-ready pixel frames. These frames are stored locally and prepared for rendering once the drone is in motion.[42]

C. Flight Operation Workflow

1) Arming and Take-off: Once all systems are initialized, the drone is armed and lifted off the ground. The KK controller handles the core stabilization tasks—maintaining roll, pitch, and yaw control using its built-in PID algorithms.[47]

2) Payload Compensation: Because the POV system adds extra weight and changes the drone's balance, the controller compensates automatically to maintain stability during flight.

3) Hover and Manoeuvring: The drone maintains a steady hover to provide optimal conditions for POV display. Pilot inputs guide basic movements while the LED subsystem continues operating in the background.

D. POV Visualization Workflow

1) Rotation Detection: The ESP32 estimates the rotational timing needed to generate the persistence-of-vision effect. This can be done using internal timing logic or optional IMU feedback.

2) Frame Rendering: As the drone rotates, the ESP32 activates LEDs in rapid slices of the final image. When seen by the human eye, these slices blend together and form a complete picture or text pattern.

3) Real-Time Pattern Adjustment: Through the web interface, users can change brightness, colour, animation speed, or switch display content. These updates immediately without interrupting flight stability.[15]

4) Synchronization With Flight Conditions: The rendering algorithm adjusts dynamically to changes in the drone's yaw speed. This allows the POV image to remain clear even if the drone changes orientation.[42]

E. System Monitoring and Shutdown

- **Runtime Monitoring:** Throughout operation, the system keeps track of battery voltage, ESC and motor temperatures, and LED power consumption. Detecting abnormal values prompts a safe- landing response.
- **Landing and Power-Off:** Once the mission is complete, the drone performs a controlled descent. The KK controller disarms the motors, and the ESP32 shuts down its Wi-Fi services before the system is fully powered off.[8]

F. Block Diagram

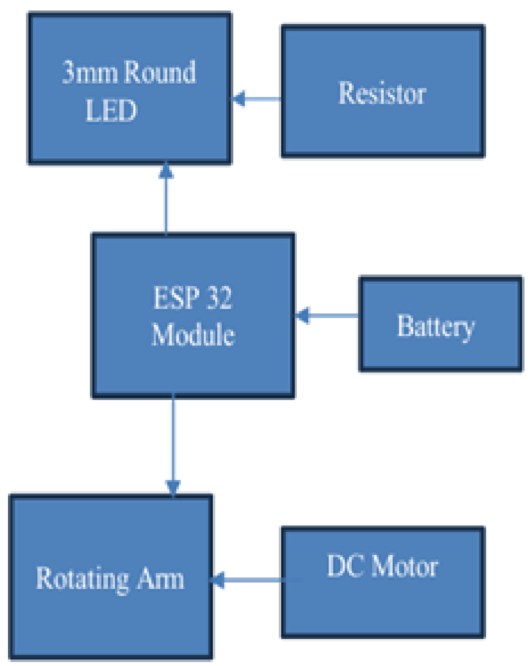

Fig1: -This the block diagram of POV LED Display system involving components 3mm round led, resistor, Esp32 as microcontroller, Battery, DC motor, Rotating Arm.

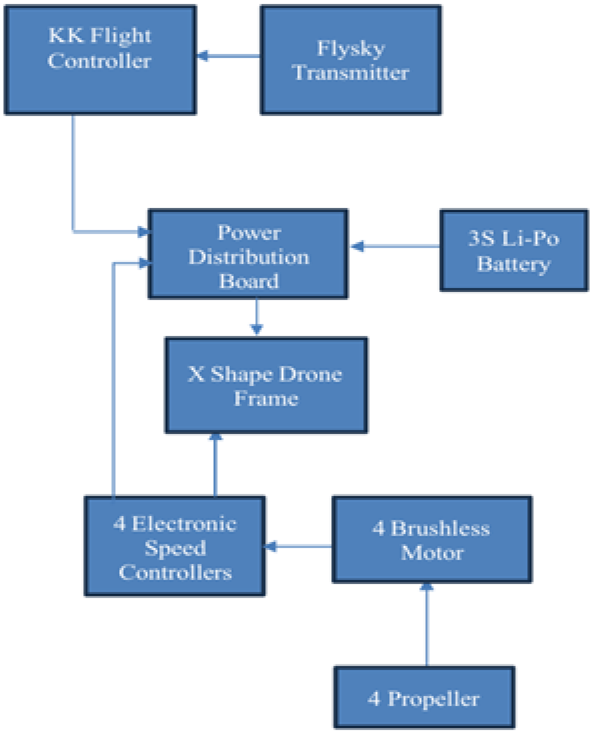

Fig2: - This is block diagram for drone involving components KK Flight controller, fly sky transmitter,3S li- po battery, four electronic speed controller, four brushless motor with propeller attached connected to power distribution board for even power distribution, all attached to X-shaped drone frame.

V. PREVIOUS WORK COMPARISON TABLE

Several POV and LED-based drone systems have been developed in previous years, but most focused on either flight control or LED visualization ,one project is there which integrates both technology persistence of vision led display mounted on drones but the author has used Pixhawk controller which is very expensive microcontroller an again the author has faced problem of vibration which is created due to air and the image generated is also not stable.

DRONE+ POV Previous Study Comparison Table

Sr.No	Reference	Type	Features
1	Anhua You et al Journal of Physics Conference,2 022	Drone-mounted POV	Stable flight; complex integration Creating vibrational issue due to instability.
2	Espressif Systems, "FlyinDiamo nds:Light Show Controller Basedon ESP32	LEDLight Show Drone	Synchronized multi-drone display
3	Joseph's 2024"POV Display using ESP32"	POV System	Display system using Esp32
4	Our Project	Drone+ POV System	Integration of two technologies, Generating complex, animation in mid air

This comparison highlights that before previous work carried on either drone or Pov systems, there is only on work which has been carried out but that is partial success as the image generated in mid-air is unstable, we will be resolving this issue by adding a little weight to POV system which will help in stabilizing POV system attached at bottom of drone. The drone will also include a WI-FI server system. The current system, therefore, presents a unique integration of both technologies, aiming for practical, educational, and entertainment purpose.

VI. APPLICATION OF SYSTEMS

The combination of a quadcopter platform with a Wi-Fi- enabled POV LED display opens up several practical and creative opportunities across different domains. Because the display content can be updated wirelessly and rendered in real time, the system offers flexibility for both experimental and operational use.

1) **Aerial Messaging and Advertising:** By projecting text or simple graphics during flight, the system can serve as an aerial communication tool for outdoor advertising, event promotion, or public announcements. The rotating LED display enables messages to be visible even when the drone is moving or hovering at a fixed point.
2) **Entertainment and Visual Art:** The ability to create dynamic visual patterns, animations, and logos makes the system suitable for artistic applications such as light shows, festivals, or performance events. The wireless interface allows creators to modify visuals instantly,

supporting interactive or synchronized effects.[17]

3) **Education and Research**: Because the setup combines flight control, microcontroller programming, wireless communication, and embedded graphics [46], it offers a hands-on teaching platform for engineering and robotics students. It can also be used in research exploring UAV-based displays, human–drone interaction, or novel communication modalities
4) **Public Safety and Navigation Assistance:** With suitable modifications, the system could assist in scenarios where visual signaling is valuable—such as search-and-rescue missions, nighttime operations, or crowd guidance during emergencies. Simple icons or indicators can be displayed to communicate with people on the ground.[14]
5) **Interactive IoT Demonstrations**: The built-in Wi-Fi webserver enables real-time user interaction, making the system useful for demonstrations of IoT concepts, remote data control, and wireless visualization technologies. This interactivity can support workshops, exhibitions, and technology outreach events.[11]

VII. CHALLENGES OF SYSTEM

While the combination of a quadcopter platform with a Wi- Fi-controlled POV LED display shows promising capabilities, the development process revealed several technical challenges that must be addressed to ensure reliable and consistent performance.

1) **Mechanical Stability and Vibration:** The addition of the POV module introduces extra weight and shifts the drone's center of gravity. This can generate unwanted vibrations that interfere with IMU readings and compromise flight stability. Achieving a balance between effective vibration damping and maintaining a rigid, lightweight structure remains a significant engineering challenge.[20]
2) **Power Distribution and Battery Load**: Both the flight system and the LED display rely on the same Li-Po battery. During rapid throttle changes, the increased power demand can lead to voltage drops, affecting both motor responsiveness and LED brightness. The extra load from the display also reduces available flight time, making efficient power management essential.[13]
3) **Timing and POV Synchronization**: Producing a clear persistence-of-vision image requires precise timing of LED activation. Changes in yaw rate, wind disturbances, or pilot maneuvers can disrupt this timing and distort the displayed pattern [42]. Since the current system relies mainly on internal timing, mismatches between expected and actual rotational speed can reduce image clarity.
4) **Wireless Interference and Communication Limits:** The system operates two wireless communication links in the same 2.4 GHz band:

- the flight control radio link, and
- the ESP32's Wi-Fi access point.

Running both simultaneously increases the risk of interference, reduced range, or occasional data loss. Ensuring reliable communication while avoiding conflicts in the shared spectrum poses a notable challenge.

5) **Heat Generation and Component Stress:** Sustained high-speed LED switching combined with active Wi- Fi communication causes the ESP32 and LED driver circuits to sync up. Within the compact drone frame, airflow is limited, and elevated temperatures can degrade performance or shorten component lifespan [10]. Effective thermal management must be achieved without adding unnecessary weight.
6) **Real-Time Processing Constraints:** The ESP32 must handle multiple time-critical tasks, including wireless data exchange, LED frame buffering, and high- frequency LED control [39]. These parallel demands push the microcontroller close to its processing limits. Any delay or interruption in execution can lead to flickering or incomplete POV images, especially when the drone rotates at higher speeds.
7) Environment Limitation Outdoor testing introduces factors such as sunlight glare, wind, and temperature variations. Bright daylight reduces POV visibility, while wind gusts can disturb rotational stability [47] and distort image

rendering. These environmental conditions impose limitations on where and when the system can operate effectively.

8) Safety Considerations Attaching a rotating LED module introduces additional safety concerns. Exposed moving parts, increased inertia, and changes in drone dynamics require careful testing and operational awareness [31]. Ensuring safe operation around people is essential, especially for advertising or event-use scenarios.

VIII. FUTURE DEVLOPMENTS OF SYSTEM

While the current prototype successfully demonstrates that a quadcopter can carry and operate a Wi-Fi-controlled POV LED display, several promising directions remain for advancing both performance and practical usefulness. These improvements can help transition the system from an experimental platform into a more robust and versatile aerial display technology.

1. Closed-Loop Synchronization Using On-Board Sensor Feedback At present, the ESP32 relies primarily on internal timing to generate the persistence-of-vision patterns. Although functional, this open-loop approach limits the clarity of images when the drone experiences rapid yaw changes or environmental disturbances. Future versions may incorporate real-time rotational feedback from the drone's IMU or an auxiliary sensor such as a magnetometer or rotary encoder. Integrating this data into the rendering process would enable precise synchronization of LED activation with the drone's angular velocity, resulting in sharper, more stable visual output.[43]
2. Multi-Drone POV Formations Another exciting direction is the expansion from a single- drone system to coordinated multi-drone displays. Swarm- based formations could generate large-scale images, sweeping animations, or volumetric light structures in the sky. Achieving such coordinated patterns would require reliable communication protocols, distributed timing synchronization, and collision- aware flight algorithms. These developments could open pathways to new applications in entertainment, outdoor events, and public communication.[38]
3. Enhanced Display Resolution and Color Fidelity The current POV module demonstrates fundamental display capability, but there remains considerable room for visual improvement. Upgrading to higher- density LED arrays or more advanced RGB addressable strips could provide finer spatial resolution and richer color depth. Such enhancements would bring the system closer to professional-quality aerial graphics while preserving the lightweight design required for drone flight.[45]
4. Battery Optimization and Power Management Strategies Energy consumption remains a limiting factor for both flight endurance and display brightness. Future work may explore optimized LED driving algorithms, power-efficient microcontrollers, or redesigned battery distribution systems[25]. Using lightweight materials and improving thermal efficiency could further reduce power overhead and extend operational time.
5. Integration of Autonomous Flight Capabilities Incorporating GPS-assisted navigation, visual odometry, or waypoint-based autonomous flight could allow the drone to execute predefined display missions with minimal operator input [22]. This would enable consistent, repeatable flight paths— critical for applications such as advertising, coordinated performances, or research experiments. Autonomous features would also free the pilot to focus exclusively on display configuration and system monitoring.
6. Environmental Adaptation: Future work may explore adaptive brightness and anti-glare techniques to improve visibility under different lighting conditions. Weather-resistant LED modules could further expand outdoor usability.[31]
7. Cloud Connectivity and Remote Content Upload: Integrating cloud storage or MQTT-based communication would allow remote users to upload display content from anywhere, expanding the system's role in IoT and smart-city applications.[11]

IX. CONCLUSION

This paper presented the development of a quadcopter system enhanced with an ESP32-driven persistence-of- vision (POV) LED display. The goal was to explore how a basic, beginner-friendly drone platform could be combined with a lightweight visual display to create a low-cost and flexible aerial communication tool.[49] By detailing the design approach, hardware integration, software configuration, and complete system workflow, the work demonstrated that both subsystems can operate together without interfering with each other's performance. Testing confirmed that the drone is capable of stable flight while the ESP32 simultaneously renders dynamic POV patterns controlled through a simple Wi-Fi web interface.[46]

This shows the feasibility of using small UAVs not only for mobility but also as platforms for real- time visual output, supporting applications such as aerial messaging, educational demonstrations, and interactive IoT showcases. At the same time, several challenges were observed— including vibration effects, power limitations, and the difficulty of maintaining precise timing for POV imagery. These insights point to opportunities for improvement in future versions of the system. In summary, this prototype provides a practical starting point for further work in drone-based display technology. Future enhancements such as autonomous flight, higher- resolution LED arrays, multi-drone coordination, and cloud- connected content delivery could significantly expand the capabilities and usefulness of this aerial display concept.

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