Design and Development of An Innovative Traffic Management System Using Drone: Kapi Dhwaja

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Abstract. Integrating drone technology in traffic management offers an innovative solution to congestion and road safety challenges by providing aerial surveillance and real-time control. Equipped with high-resolution cameras and speakers, drones can stream live footage to a central control station, enabling law enforcement to monitor traffic conditions remotely and communicate with drivers and pedestrians without needing a physical presence. This approach enhances traffic regulation, reduces response times, and improves safety, particularly in congested or high-risk areas. Future advancements, including AI-driven traffic analysis and smart city integration, will further optimize traffic monitoring and enforcement, making urban mobility more efficient and secure.

Keywords: Drone, traffic congestion, wireless communication system, surveillance, real-time control.

1 Introduction

Road safety, farming, traffic congestion management are becoming serious challenges in urban and rural area [1–2]. Remote highways, congested zones and accident-prone areas are often challenging to Number the trend in number of high throughput of vehicles, poor driving habit and many violations indicates that a smarter and flexible traffic control system is required [4]. One innovative application to solve these problems is for example drone-based traffic surveillance 1. Equipped with a high definition Camera-equipped and wireless communicating drones can offer real-time aerial surveillance [6], enabling law enforcement to observe traffic flows, identify violations, and promptly respond to incidents. Unmanned aircraft, compared to the fixed surveillance devices, bring with them the flexibility of a wide coverage area, for example covering crowds and hard-to-reach locations in general, and improvements on traffic control in particular.

To enhance law enforcement abilities, to reduce traffic violations [7] or just for making our roads safe, we propose an automatic smart traffic monitoring system using model of Drones. Drones could also revolutionize traffic control with the help of AI-driven analytics and real-time communication, for more efficient movement and law enforcement. This is consistent with

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the objectives of intelligent transportation systems that utilise technology to make traffic management more efficient and adaptable.

2 Problem Statement

Road safety and traffic congestion 1 are a problem in urban and rural areas, as they are filled with poor enforcement and monitoring that end up in violations, delays, and accidents on a regular basis. Most existing solutions for traffic regulation involve human intervention, which can be time-consuming, resource heavy and ineffective in dangerous [3] or hard-to-reach areas. Reckless driving, no police manning, and poor monitoring [6] [7] complicate matters. This is an unacceptable situation, and we need a better system of real-time monitoring that will lead to better response times and traffic control." Integration with drone technology [8] can help in aerial surveillance, real-time monitoring, and remote communication with the traffic management, making the approach of managing today's roads to be more flexible and efficient traffic control issues.

3 Objectives

1. Thermal control, which prevents overheating when operating for extended periods of time. It is a good choice for long-duration drones because of its low electromagnetic interference (EMI), which makes integration with onboard electronics easier. IoT Integration in Traffic Monitoring
2. Resource Utilization Optimization in Traffic Management
3. IoT-Powered Smart Traffic Regulation Improvement [2]
4. Identifying Illicit Activities in Traffic Areas [3]
5. Drone with External Wireless Communication System.

4 Layout of The Project

The circuit's components are listed. The circuit diagram that will be used is a block diagram. describing the actions and processes that need to be taken. writing and developing the complex processes. obtaining the results and trying to do more improvisation. observing the field's progress and the potential for more study.

5 Components

5.1 EMAX 935KV Brushless Motor

5.2 Hobbywing Xrotor 40A ESC

5.3 DJI Naza M V2

5.4 S500 Carbon Fiber Frame

5.5 Skydroid T12 Transmitter and receiver

5.6 Wireless Communication System

5.7 Wireless Transmitter and Receiver (UHF/VHF System)

5.8 Audio Amplifier

5.9 Calibration of Drone

5.1 EMAX 935KV Brushless Motor

The EMAX 935KV brushless motor (Fig.1.) is a high-performance drone motor that is characterized by efficient power transmission and stable running. It is specifically designed for medium-speed applications requiring high torque and is commonly applied in aerial photography, surveillance, and mapping drones, where stability in flight and energy efficiency matter. Lightweight construction and optimized winding contribute to better thermal management, Thermal control, which prevents overheating when operating for extended periods of time. It is a good choice for long-duration drones because of its low electromagnetic interference (EMI), which makes integration with onboard electronics easier flights.

Fig.1. EMAX 935KV Brushless motor.

The high thrust-to-weight ratio also ensures the same consistency in the flight of the traffic management drone [5], which thereby manages to safely hover and manoeuvre, despite its payload of 350 - 500g, all while serving as the last line of observation, monitoring, and information transmission for densely populated areas and for violation tracking. Being more energy efficient of the motor, the flight time is up to 14-15 minutes and it is the best for long-time flight, train and police use or commercial applications like monitoring drone, etc.

5.2 Hobbywing Xrotor 40A ESC

The Hobbywing Xrotor 40A ESC is a high-quality electronic speed controller with a broad spectrum of use for medium sized planes. It is widely used on multirotor/ FPV racing drone to offer smooth and sensitive control. It is also critical for smoother flight performance due to the high signal precision and reliable MOSFET heat reduce system. Furthermore, its low-resistance PCB layout reduces power loss for leading drone performance and energy savings.

Fig. 2. Hobbywing Xrotor 40A ESC.

The multidirectional Hobbywing Xrotor 40A ESC (Fig. 2.) provides you convenient application and simple plug in mode of a traffic management drone with the motor and flight controller. For the public security, law enforcement collaboration and the real-time vehicle monitoring, (in case of) there is demand to maintain the altitude and the location, therefore the high-speed response is guaranteed. Efficient power distribution and smooth throttle modulation are the key to such a sweet experience of flying.

5.3 DJI Naza M V2 Flight Controller

Visibly Popularized: By far for a lot of quadcopters (has, hexa, octa),- DJI Naza M V2 Flight ControllerIf you are looking for the best flight controllers for smooth navigation and computerized flight, most quads, hexa and octo are equipped with this flexible, trustworthy controller. 2 and Mapping Enabled – allows the drone the ability to not only plan out its route of flight but also come equipped with easy level controls and stabilized flight capabilities due to the precision of its IMUs (inertial measurement units) and GPS connectivity. The three modes of flight can be changed between Manual, GPS and Attitude (ATTI) modes, switching between manual and autonomous control, making it able to be widely utilized in commercial UAV applications (fig. 3).

Fig. 3. DJI Naza M V2 Flight Controller.

Features: The Naza M V2 makes flight control easy to achieve and is a perfect match for your Traffic Surveillance Drones to fly in a stable way, as well as perform programmed surveillance tasks. Thanks to GPS-assisted hovering the drone can observe high-traffic areas without needing constant manual interventions. Fail-safe return to home (RTH) means the device will come home if it loses connection.trust the machine will return. What's more, easy integration for on-board payloads, such as speakers and cameras, allows effective coordinating on law enforcement, public addressing and traffic management.

5.4 Skydroid T12 Wireless Transmitter and Receiver

TheSkydroid T12 (fig. 4,5,6) is a transmitter and receiver system for long range UAV communication with high precision and low latency. It provides dependable telemetry and real-time command execution over a range of up to 20 km. The system is suitable for professional drone flights, featuring seamless flight communication, multiple channel settings, and accurate control. Its FHSS (frequency-hopping spread spectrum) technology and digital signal processing prevent interference while providing a secure and stable connection in urban or high-interference surrounding.

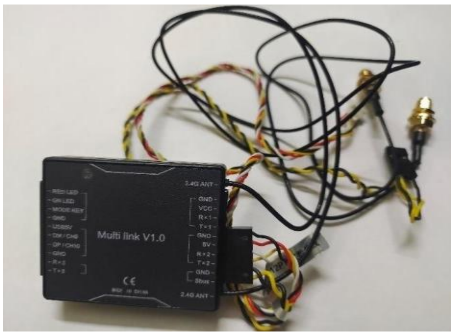

Fig. 4. Receiver.

Fig. 5. Transmitter.

Fig. 6. Camera.

5.5 8400mAh 4S2P Li-ion Drone Battery

The 8400mAh 4S2P Li-ion battery (fig. 7) is a high capacity power bank that can be used to provide a longer-lasting drone flight and efficient energy management. It's more energy dense and has a longer life cycle than LiPo, so it's perfect for long duration mapping, monitoring and surveillance missions. And with a constant discharge rate and a voltage output of 14.8V, our battery delivers reliable power with low voltage drops and power cut.

Fig. 7. 8400mAh 4S2P Li-ion Drone Battery.

This battery with longer flight time -the extended 12miles of signal range and 5780 feet of height range, and eliminating times for recharging so long as they are extendable, the actual time may slightly differ, as affected by fringe Use Tim Extend the Battery Life of Your Drones When your drone starts to lose power during flight, it's a natural beauty to light up the eyes to show the power for their battery. And even loaded with such equipment as cameras, speakers and communication networks, the baby plane is stable in the air, due to its light weight too. The continuous power output ensures a steady power supply for drone traffic control systems, thanks to the stable energy release. which guards against unexpected power outages and guarantees continuous traffic monitoring, surveillance, and real-time public announcements.

5.6 S500 Carbon Fiber Frame

The S500 Carbon Fiber Frame (fig. 8) is a quality yet rugged frame which offers a high level of strength and rigidity and makes it ideal in FPV application. The high strength to weight ratio and carbon fiber construction makes it the perfect material for high performance drones. With a 550mm wheelbase, the XT46-HRC frame enables you to easily mount the critical GPS, camera and communication systems to reduce vibration, offering precise sensor performance and deeper stable flight.

Fig. 8. S500 Carbon Fiber Frame.

For real time, continuous overhead surveillance and publicity broadcast, the S500 frame can provide reliable hovering and easy to fly manoeuvres to traffic control drones. Its high security can bear Speakers, Cameras, and Real-time Monitoring etc. and it can bear 350-500g. Due to its robust reasons, we use the UAV because it is insensitive to wind and has support for long flights, that we take advantage of for traffic monitoring applications.

5.7 UHF/VHF Wireless Communication System

With the UHF/VHF Wireless Transmitter/Receiver System you'll always have clear, completely reliable two-way communication. It is donating dável in structures Violence and networks of drone law enforcement by emergency service to transfer audio up to two KM, obtapparates in frequency band of 400MHz to 470MHz!

This system enables live transmission of public announcements, safety warnings, and emergency alerts to traffic control drones. Its long range of transmission guarantees an effective coverage, especially in urban environment where interference are frequent. It is

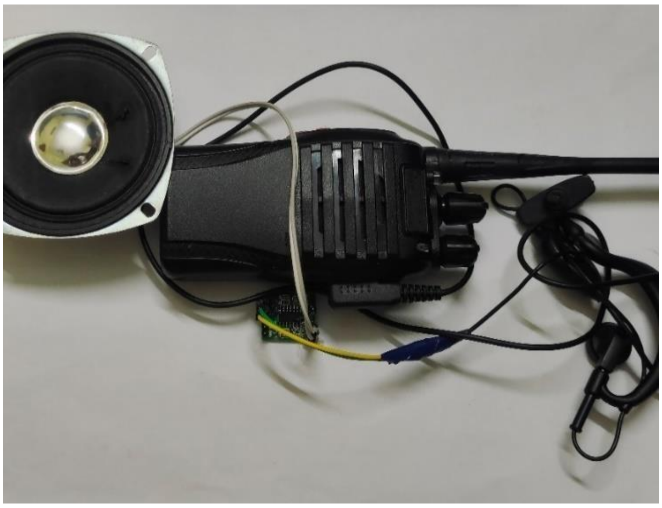

Fig. 9. UHF/VHF wireless communication system.

Due to its low power consumption, that guarantees extended uptime and continuous dissemination of important information’s by traffic control teams, it is a valuable aid for intelligent traffic surveillance and support regarding law enforcement (fig. 9).

5.8 PAM8403 Audio Amplifier

A small, compact audio amplifier that uses ST Microelectronics Class-D PAM8403 Class-D power amp chip (fig. 10) is ideal for portable use where an amp will be exposed to the elements. Economical 5V operation at 3W per channel makes it suitable for many speaker striations, embedded communication systems and portable audio applications. In addition, the amplifier is suitable for any desired applications that need amplified and performance sound quality, while not consuming large amounts of current on the low distortion, low heat dissipation, and high signal integrity.

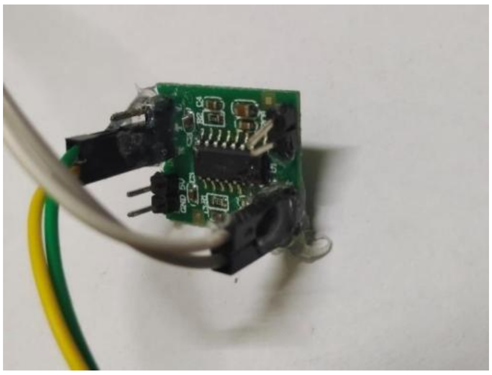

Fig. 10. PAM8403 Audio Amplifier.

Even in crowded city, the energy-saving design of this drone enables it to fly for over 1½hrs and make a loud and clear sound. Tellingly, the PAM8403 amplifier allows for clear audio transmissions, which can't be overstated for the role they play in smart traffic control and police drones to share live traffic updates as well as safety and emergency broadcasts.

5.9 4-Ohm, 5-Watt Satellite Speaker

The 4-ohm, 5-watt satellite speaker (fig. 11) is tiny and easy to carry, but not small in sound quality, it provides clarity and punch while consuming less power. Its impedance optimized construction allows for sound transmission even in loud environments, enabling the use of lightweight drones, built-in audio applications and mobile communications systems.

Fig. 11. 4-Ohm, 5-Watt Satellite Speaker.

This speaker is used with the PAM8403 amplifier and a traffic control drone to transmit public and emergency messages. For reasons of weight, only one speaker is installed, guaranteeing clear voice output and leaving ample battery power even after long flights. This configuration is critical for those air traffic monitoring and communication systems in which it allows the drones to disseminate traffic information, traffic law enforcement and law enforcement in general in real time.

6 Implementation

The overview block diagram of petroleum-stations wheeled robot petroleum The Overall Diagram of the Petroleum Stations Shear Robot 6.2.1 The Petroleum Station Shear Robot and Visual Process (i) The Hardware System of the Visual System It includes 2-D Code line scanner, monitor, Gamma correction circuit, light, and Zou J, Liu Z (2007) The flow-charged control system experimental device and its application in gas transmission. This solution with aerial surveillance and communication is designed to assist the police in traffic surveillance, command, and security. Its three main components the Police Control Room, Flight Controller System, and the Wireless Communication System are indispensable to the functioning of the drone. The Police Control Room, the control hub, and the local vehicle patrol are responsible for controlling officers who control flies in the sky [5] and talk with the public. It is equipped with an RF RC transmitter/receiver that allows precise remote control of the drone with the RF signals. The onboard speakers in the drone can also pick up voice commands from the UHF/VHF transmitter. The RF Transmitter/Receiver transmits commands between the control room and the drone perfectly. A high definition camera takes continuous live images, offering live traffic congestion information, roadblocks, emergency events and the like.

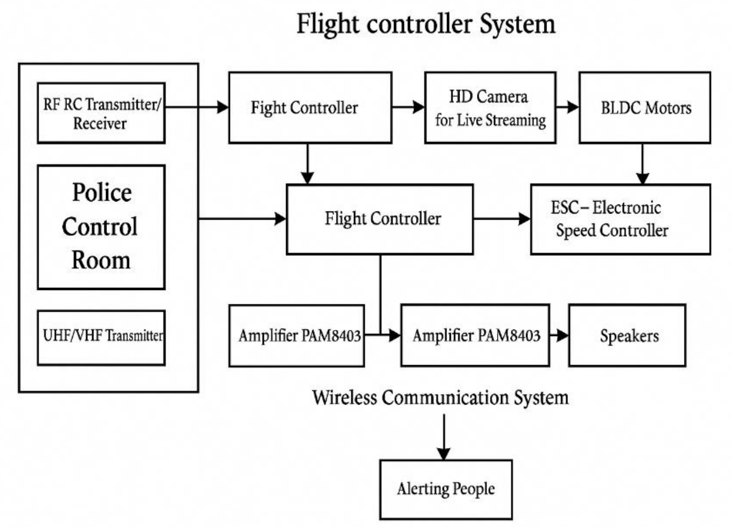

Fig. 12. Block Diagram of Traffic Management Drone with Wireless Communication System.

Fig. 12 shows the block diagram of traffic management drone with wireless communication system. The flight controls that host accelerometers and gyroscopes process the movement instructions while keeping the drone afloat. The power of the brushless DC (BLDC) motors is maintained by the Electronic Speed Controller (ESC) ensuring balance and accurate speed control. Due to the qualities like efficiency, long life, low maintenance, themes BLDC motors are better suited for long time surveillance applications 5. Police officers can use the Wireless Communication System to send live vocal messages to the public. The UHF/VHF receiver receives the control room voice. These signals are then amplified by the PAM8403 Amplifier, which is a compact digital amplifier for enhancing sound, and the sound distortion will be reduced as well. Loudspeakers are speakers that reproduce messages which are amplified in order to ensure that the public announcements are audible above background noise [2]. In this configuration, the drone becomes a moving public address system, allowing the police to broadcast emergency messages, issue orders and enforce traffic laws. The final phase is called Attentioning People, and it stands for achieving a good penetration and dissemination in the minds of pedestrians and commuters. In summary, such drone based system enhances emergency response, enforcement and traffic management. For public awareness and law enforcement commands, the Voice Transmission is smooth via the Wireless Communication, and stable surveillance and smooth navigation are ensured through the Flight Controller [9]. This system provides the new idea for traffic monitoring, road safety, and emergency management using state of the art tech flight control and communication technologies [10], [11].

7 Working

With the integration of the Flight Controller System and the Wireless Communication System, a traffic management drone [1] can support the law enforcement to observe the road conditions, send real-time information [8], and survey at height to maintain the public security. The system is primarily composed of the Flight Controller and Police Control Room system, wireless communication system, and are the most vital components in the total operation of drones [9]. They command the drone from the Police Control Room while being miles away from the site using an RF RC Transmitter/Receiver that sends RF signals for controlling the drone to control its movements. Meanwhile, long-range communication with minimal interference is achieved with the help of a UHF/VHF transmitter that plays voice messages to the drone's supercool speakers. Flight Controller System that keeps the drone connected with the control room seamlessly using an RF transmitter/ receiver and handles navigation, aerial surveillance, and thrusting management. The Flight Controller with gyroscope and accelerometer onboard stabilization not only stabilizes the drone, it also processes data and records live aerial footage of traffic jams, accidents and road conditions movement instructions. There are brushless DC (BLDC) motors responsible for thrust generation and maintaining flight stability. These are operated by an electronic speed controller (ESC) which controls the feeding power [10]. These motors are used very often, they are efficient, durable and require low maintenance which makes them great for long range flights. Fig. 13 shows the traffic management drone.

Fig. 13. Traffic management drone.

The wireless communication system uses a UHF/VHF receiver to record voice commands, which are then processed and amplified by a PAM8403 amplifier to guarantee crystal-clear sound output through powerful speakers. This allows for real-time public announcements. With this configuration, the drone can act as an aerial public address system, supporting emergency communication, pedestrian guidance, and traffic enforcement. The last step, Attentioning People, makes sure that pedestrians and drivers alike receive critical messages in an efficient manner. Using cutting-edge aerial technology, this integrated system improves emergency response, traffic regulation, and law enforcement effectiveness while offering a dependable option for real-time traffic monitoring, congestion control, and public safety interventions [2].

8 Design Equations

Drone-Generated Thrust (T):

In a multirotor drone, thrust is produced when the motors start turning the propellers, creating an upward force that defies gravity. According to Newton's Third Law of Motion, this is caused by aerodynamic forces, in which the drone is propelled upwards by the rotation of the propeller blades pushing air downward at a high speed, producing an equal and opposite reaction force. The more thrust there is, the more airflow is forced downward by the motors' increased rotation.

$$T = T_e \times \rho_a \times A \times (rpm \times p/60)^2 \quad (1)$$

The estimated thrust per motor for the brushless motor EMAX 935KV with 10x4.5-inch propellers operating at 11.1V (4S2P Lithium ion battery) and an estimated RPM of 10,300 is roughly 900g (8.83N). Since the drone is a quadcopter, its total thrust is:

$$T_{total} = 4 \times 8.83N = 35.32N \quad (2)$$

Lift Force

Although it is calculated differently in aerodynamics, the lift force generated by the propellers is comparable to thrust. Lift (L) is the aerodynamic force perpendicular to the airflow that results from the propeller blades' motion, whereas thrust (T) is the force that the propellers apply to counteract gravity.

The lift force is computed by using the Lift Equation:

$$L = \frac{1}{2} L_e \rho_a A V^2 \quad (3)$$

Xrotor 40A ESC Power Calculation:

The fundamental electrical formula can be used to calculate the power used by the Xrotor 40A Electronic Speed Controller (ESC):

$$P = Voltage(V) \times Current(I) \quad (4)$$

where V is the voltage applied to the ESC, I is the current it draws while operating, and P is the power in watts. This relationship aids in calculating how much electrical power the ESC manages overall when managing the motor. For example, 360 watts of power would be used if the ESC ran at 12 volts and pulled 30 amps of current. This computation is necessary to choose appropriate power sources and guarantee effective thermal control in drone systems.

Esc Efficiency Calculation:

The efficiency of an Electronic Speed Controller (ESC) can be calculated using the formula:

$$\eta = \frac{P_{output}}{P_{input}} \times 100 \quad (5)$$

where Poutput is the power supplied to the motor, Pinput is the total power received from the power source, and η is the efficiency expressed as a percentage. This computation aids in figuring out how well the ESC transforms electrical energy from the battery into motor power that can be used. A higher efficiency number denotes better system performance overall and less energy loss, typically in the form of heat.

Frame Load Distribution:
The load distributed across the drone's frame can be calculated using the formula:

$$F_{total} = F_{motor} + F_{payload} \tag{6}$$

where Ftotal is the total force acting on the frame, Fmotor is the total force or weight produced by all of the motors and associated parts, and Fpayload is the force caused by any extra weight the drone is carrying, like speakers, cameras, or sensors. To make sure the drone's frame can withstand the entire mechanical stress without bending or failing during flight, this equation is crucial to structural analysis.

Thrust-to-Weight Ratio (TWR):
The Thrust-to-Weight Ratio (TWR) is calculated using the formula:

$$T_{wR} = \frac{T}{w_d} \tag{7}$$

where wd is the drone's total weight, including its frame, electronics, and payload, and T is the total thrust generated by all of the drone's motors. The drone's capacity to raise itself off the ground and execute steady maneuvers is indicated by this ratio. While a value near or below 1 indicates limited lift capability, a TWR greater than 1 indicates the drone can ascend. This measure is essential for assessing flight performance and guaranteeing effective vertical takeoff and control.

9 Connections

1) The RF RC Transmitter/Receiver in the Police Control Room sends control signals to the drone for navigation and maneuvering.
2) The RF signals are received by the drone's RF Transmitter/Receiver, allowing real-time communication for flight control.
3) The Flight Controller processes navigation inputs and activates the HD Camera to stream real-time video footage back to the control room.
4) The Flight Controller sends signals to the ESC, which regulates power to the BLDC Motors for stable flight operation.
5) The Electronic Speed Controller (ESC) controls the Brushless DC (BLDC) Motors, adjusting their speed and power for smooth drone movement.
6) The UHF/VHF Transmitter in the control room sends audio messages for public announcements to the drone's communication system.
7) The UHF/VHF Receiver on the drone receives the transmitted voice commands.
8) The received audio signals are sent to the PAM8403 Amplifier, which boosts the sound output for better clarity.
9) The amplified audio signals are transmitted to the speakers, ensuring loud and clear public announcements.
10) The final output is delivered to the public through loudspeakers, alerting them with traffic-related announcements and instructions.

10 Results

The drone system used for traffic surveillance and public announcements successfully demonstrated real-time communication and stable flight control. The RF transmitter installed in the Police Control Room transmitted signals to the drone's onboard RF receiver, enabling smooth navigation and quick movement. During the testing phase, the drone responded rapidly to directional commands, even when it was far away. The Flight Controller efficiently processed the inputs and maintained the drone's stability with the help of ESCs and BLDC motors. Together, these components ensured that the drone flew in a controlled and balanced manner. This proved that using these drones for patrolling, real-time traffic monitoring, or search and rescue missions where quick navigation and continuous movement are essential is feasible.

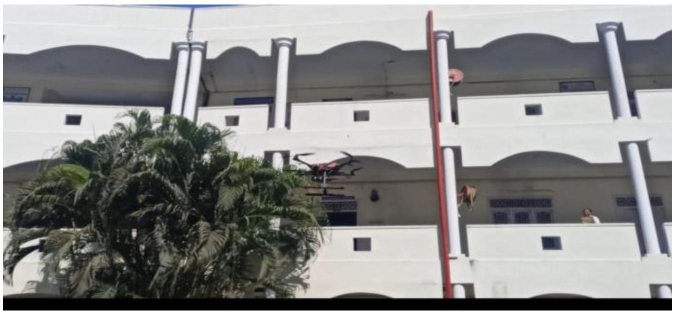

Fig. 14. The drone was flown to check its stability in the open area.

The drone's HD camera transmitted a consistent, high-definition video stream to the control room during the testing phase (fig. 14 & 15). This live video stream allowed for the real-time observation of traffic, crowd movements, and environmental conditions from above. Even when the drone was moving or experiencing mild turbulence, video capture remained stable due to the camera's communication with the Flight Controller. This feature could significantly increase public safety, especially in areas with high car densities or during public events. Authorities can save time and money by remotely monitoring specific areas without deploying ground troops. It's also possible to save the recorded video for later analysis, which would be useful for recording or analyzing traffic violations occurrences.

Fig. 15. Live drone footage instructing students to use the footpath.

The public announcement capabilities were tested using UHF/VHF communication modules, and the results were very positive. Voice communications from the control room, either live or pre-recorded, were successfully received by the drone's onboard receiver. Prior to being played through the drone's loudspeakers, these audio signals were amplified and improved in quality using the PAM8403 amplifier. The announcements were loud enough to be heard in public areas, including crowded areas and by the side of the road. This method can be very helpful when creating emergency messages, guiding traffic during traffic jams, or warning the public during disasters. The entire communication system was free of noticeable lags and distortions.

Results Drive Links:

1) https://drive.google.com/file/d/1eNnpMHdyZ3KjpPz3er4sP_ZDsE0VIsnX/view?usp=drivesdk
2) https://drive.google.com/file/d/1eZ99MsuHX76GbBO7G3lCqnycg7Am70Ph/view?usp=drivesdk
3) https://drive.google.com/file/d/1eZyScJ9h-qfm8uk01NduuXlmY2iwvHco/view?usp=drivesdk
4) https://drive.google.com/file/d/1cOW6zMoDWnwodopawAhc7vuXyaBjvg7P/view?usp=drivesdk

Several demonstration videos were filmed and distributed via secure drive links in order to verify the system's functionality. The drone's communication capabilities, steady flight behavior, and real-time responsiveness are all skillfully demonstrated in these videos. One of the videos shows the drone flying steadily while moving dynamically through an open space, demonstrating how the Flight Controller controls the ESCs, BLDC motors, and RF transmitter-receiver module.

Another video shows the high-resolution live video feed that was sent back to the control room. Real-time traffic flow and pedestrian activity monitoring was made possible by the clarity and continuity of the images during flight. A night vision segment is also included in the video, demonstrating the drone's capacity to function in low light levels without sacrificing the quality of its surveillance. One video also showcases the public announcement system, in which a PAM8403 module amplifies voice messages before the drone broadcasts them clearly through onboard speakers. These real-world examples provide compelling proof of the system's usefulness in public safety and law enforcement situations like emergency response operations, crowd control, and traffic regulation.

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