

Aeroguard: Multi-Role Intervention Drone System

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Abstract— *Managing riots, violent protests, and emergency situations without endangering human life is a growing challenge for public safety agencies. This paper presents the design of an anti-riot drone system that supports non-lethal intervention while keeping security personnel at a safe distance from hostile environments. The proposed drone is designed to carry a controlled tear-gas dispersal unit, an electrically activated net for temporary immobilization, and an optional tranquilizer mechanism that allows animals to be handled safely when required. With the support of GPS-based navigation, stable flight control, and live high-definition video transmission, operators are able to observe developing situations from a distance and respond with greater confidence and accuracy. During large-scale disturbances, the tear-gas system helps in dispersing crowds in a controlled manner, while the electric net can be selectively deployed to restrain specific individuals only when necessary. The same platform can also be adapted for managing wildlife or stray animals through safe and non-injurious capture methods. By combining aerial monitoring with multiple non-lethal response options, the system improves situational awareness, lowers operational risk, and provides a practical and reliable solution for modern law-enforcement and public-safety operations.*

Keywords— *Anti-riot drone, non-lethal crowd management, teargas dispersal system, electric net re-straint, UAV-based monitoring, public safety support.*

I. INTRODUCTION

Maintaining public safety during riots, violent protests, and sudden incidents of civil unrest is a major challenge for law-enforcement agencies. Such situations often change quickly and are marked by high emotional stress and unpredictable crowd behavior. Conventional crowd-control methods, including water cannons, rubber ammunition, and manually launched tear gas, usually require officers to be physically close to hostile groups. This close engagement increases the risk of injury and, in some cases, can intensify the situation instead of bringing it under control. The effectiveness of

ground-based operations is further reduced in environments with poor visibility, overcrowding, and limited freedom of movement. Recent developments in unmanned aerial technology open new possibilities for handling crowd-management tasks more safely and efficiently. In this work, an Anti-Riot Drone is proposed to move key monitoring and intervention activities from ground personnel to an aerial platform. By operating from above, the drone provides continuous visual observation and supports safer, data-driven decision-making in real time. The system includes non-lethal response mechanisms such as controlled tear-gas deployment for dispersing crowds and an electrically activated net that can temporarily restrain specific individuals without causing long-term harm. Live video transmission allows authorities to monitor crowd behavior, detect emerging threats, and coordinate responses more effectively. With its mobility, accuracy, and ability to operate from a safe distance, the proposed drone system offers a practical, scalable, and cost-effective approach to improving public safety while reducing direct confrontation.

II. RELATED WORK

Kadirvel Manikandan, Reshmi Olayil, Raja Govindan, and Raja Thangavelu [1] proposed an Artificial Intelligence (AI)-based drone control system aimed at enhancing military surveillance and security operations. The system combines AI techniques with unmanned aerial vehicles (UAVs) to enable autonomous monitoring, reliable threat detection, and coordinated responses in high-risk environments. The study emphasizes advanced modeling approaches that improve object detection, tracking accuracy, and adaptive control of drones in areas vulnerable to terrorist activities. Experimental results indicate notable improvements in operational precision and system responsiveness, while also highlighting potential applications in disaster response and future developments focused on energy-efficient AI algorithms.

Anvi Priya, Sanjay Kumar, and Sanjeet Kumar [2] introduced a 5G-enabled drone swarm surveillance framework to assist paramilitary forces in detecting and countering terrorist activity in dense forest areas. The system uses an AI-driven network consisting of a mother drone and multiple micro-drones that autonomously navigate through complex terrains. The mother drone performs thermal imaging to identify potential targets, while micro-drones operate below the tree canopy to capture high-clarity images and videos. Data is transmitted back to the command center via the mother drone. The study also compares several YOLOv8 models on the HIT- UAV dataset, demonstrating improved human-detection accuracy using advanced AI and 5G technologies.

Witenberg S. R. Souza, Alexander J. Hart, Benedito J. B. onseca, Mansour Tahernezehadi, and Lance E. Christensen [3] developed a UAV system for methane gas leak detection to support gas distribution companies in infrastructure monitoring. The UAV carries a methane sensor that collects real-time concentration data, which is analyzed using Upwind Survey Regions (USRs) to identify probable leak zones. The system transforms aerial readings into ground-level survey maps that highlight vulnerable and safe regions. Field tests validated its effectiveness, showing improved detection precision and operational reliability.

Tyler C. Looney, Nathan M. Savard, Gus T. Teran, Archie G. Milligan, Ryley I. Wheelock, Michael Scalise, Daniel P. Perno, Gregory C. Lewin, Carlo Pincioli, Cagdas D. nal, and Markus P. Nemitz [4] proposed the use of air-releasable soft robots for explosive ordnance disposal (EOD). They designed a UAV equipped with a custom deployment system capable of releasing a 296 g soft hybrid robot featuring a vacuum-based flasher-roller actuator. The robot was successfully deployed from a height of 4.5 meters and autonomously navigated toward a dummy landmine, presenting a low-cost and efficient method for deploying soft robotics in demining operations.

Todd Simpson [5] proposed a real-time AI-based drone surveillance system for detecting violent crowd behavior through Human-Autonomy Teaming (HAT). The system incorporates advanced machine learning techniques such as Multitask Cascading CNN, ScatterNet Hybrid Networks, Multiscale Infrared Optical Flow, and event-based vision sensors to analyze crowd density, motion patterns, and detect violent instigators. The system employs Live Virtual Constructive (LVC) monitoring to provide law enforcement with real-time situational awareness and improve operational decision-making during public events.

III. PROPOSED METHODOLOGY

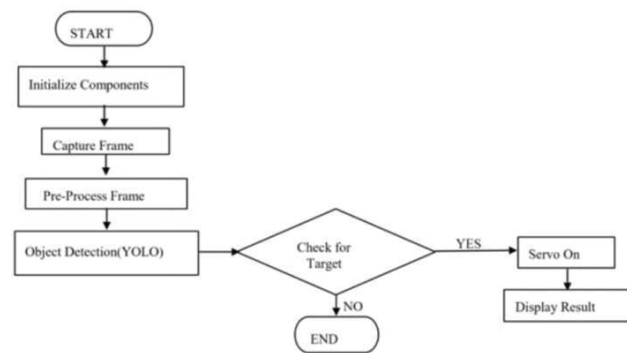


Fig. 1. Methodology

Figure 1 illustrates the general workflow of the proposed automatic anti-riot system capable of handling threat scenarios of varying nature by integrating advanced sensors, intelligent data processing, and autonomous decision-making. The on-board sensor suite continuously collects environmental and situational data from the riot-affected area using high-resolution cameras, GPS modules, and an Inertial Measurement Unit (IMU). Each sensor performs a dedicated function: the camera captures live video streams, the GPS provides accurate positional data relative to drone movement, and the IMU records orientation, acceleration, and stability parameters. Together, these sensor inputs enable the system to perceive the riot environment accurately and in real time.

Once captured, the raw sensor data is transmitted to the threat-analysis and processing unit, where algorithms evaluate crowd behavior, detect abnormal movements, and determine whether the situation is stable, escalating, or dangerous. The processed information is simultaneously displayed on a virtual remote-monitoring dashboard containing live video, system alerts, and continuous status updates, allowing the operator to oversee the situation without entering the conflict zone physically.

The system then selects the appropriate non-lethal countermeasure based on the assessed threat level. If the analysis detects a large, aggressive crowd, the drone activates the tear-gas dispersal module, releasing controlled amounts of gas at strategic points to push the crowd back and reduce pressure on both civilians and officers. This technique ensures wide-area coverage while maintaining a safe operational distance.

Alternatively, when the threat originates from a single individual—such as a violent agitator, a weapon-carrying suspect, or an escaping offender—the electric net deployment mechanism is triggered. A lightweight, electrically charged net is precisely launched toward the target to temporarily immobilize the person without causing long-term harm. Once the active threat is neutralized—either through crowd dispersion or immobilization of the suspect—the system transitions into its stabilization phase, maintaining ongoing surveillance to ensure no further disturbances arise.

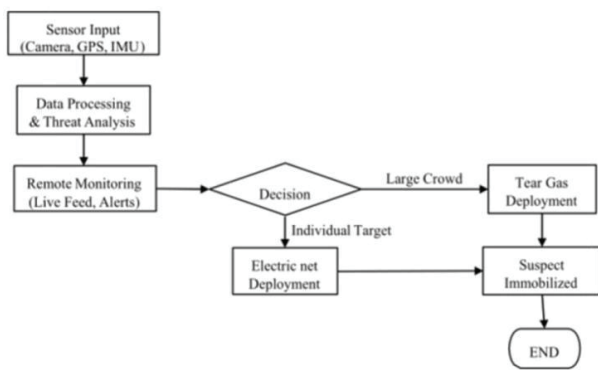


Fig. 2. Flow chart

This intelligent and automated decision-making approach minimizes human risk, enhances response accuracy, and provides law-enforcement agencies with a reliable and efficient tool for managing dangerous situations safely.

IV. CIRCUIT METHODOLOGY

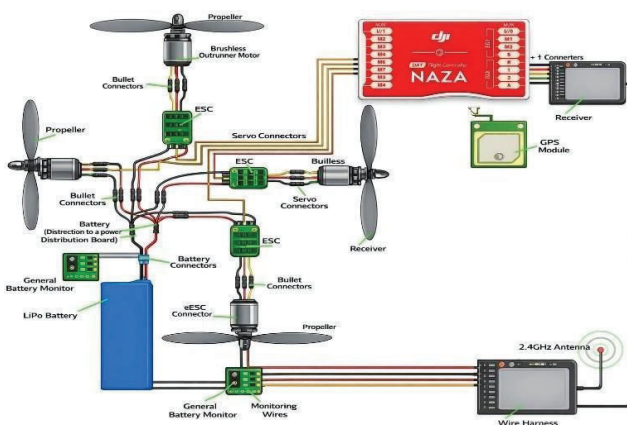


Fig. 3. Drone System

The quadcopter architecture is organized around the DJI NAZA flight controller, which serves as the central processing and stabilization unit of the system. Each arm of the drone houses a brushless DC motor that produces lift, and every motor is controlled through an Electronic Speed Controller (ESC). Power from a single Li-Po battery is distributed uniformly to all ESCs through a power-distribution board, ensuring steady and reliable power delivery. The propellers are arranged in alternating clockwise and counter-clockwise orientations to counter torque effects and maintain steady flight. The NAZA controller continuously reads data from onboard sensors—including the gyroscope, accelerometer, and barometric sensor—and dynamically adjusts motor speeds to sustain balance, correct tilts, and enable controlled movements. A 2.4GHz radio receiver transmits pilot inputs such as throttle, pitch, roll, and yaw, which are combined with sensor feedback for precise motion control. In addition, a GPS module supports advanced navigation features like position hold, automatic return-to-home, and waypoint-based flight to enhance mission reliability and safety. Overall, the system integrates power distribution, motor control, navigation,



Fig. 4. Drone Implementation

sensing, and communication subsystems into a coordinated framework that delivers stable, responsive, and efficient quadcopter operation.

The Aeroguard multi-role intervention drone system is designed using a modular approach that emphasizes safety, legality, and flexibility from the initial stage. It is built as an adaptable platform capable of handling multiple mission types with minimal changes. The system uses a stable aerial frame integrated with advanced autopilot systems like PX4 or Ardupilot, ensuring accurate navigation and reliable flight performance. A companion computer such as NVIDIA Jetson or Raspberry Pi enables real-time processing, sensor fusion, and autonomous decision-making, reducing the need for continuous manual control. To improve operational effectiveness, the drone is equipped with sensors such as high-resolution cameras, thermal imaging, and LiDAR. These sensors provide real-time situational awareness, which is essential for applications like search and rescue, disaster monitoring, and environmental analysis. The system also includes LTE/5G modules and long-range communication systems, ensuring continuous command, control, and live data transmission even in remote or large operational areas. A major feature of the Aeroguard system is its universal payload bay, which allows quick and easy attachment of non-harmful modules based on mission requirements. These modules include audio broadcasting systems, first-aid kits, searchlights, communication relays, and data collection devices, making the drone highly versatile. The Ground Control Station offers a secure and user-friendly interface with live video streaming, digital maps, mission planning tools, and geofencing alerts, ensuring safe and efficient operation. The system is developed through a structured process that includes design, prototyping, software integration using ROS2 and PX4, simulation testing, and controlled field trials. After meeting all safety standards, legal requirements, and operator training criteria, the system is approved for deployment. Overall, Aeroguard is a reliable, safe, and multi-functional drone platform suitable for civilian support, disaster response, and secure surveillance applications.

V. RESULTS AND DISCUSSION

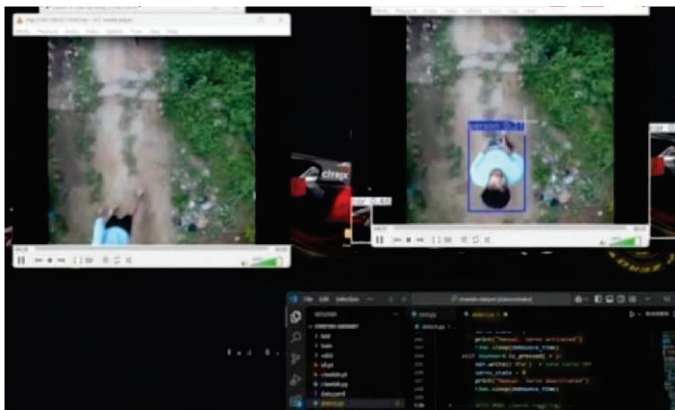
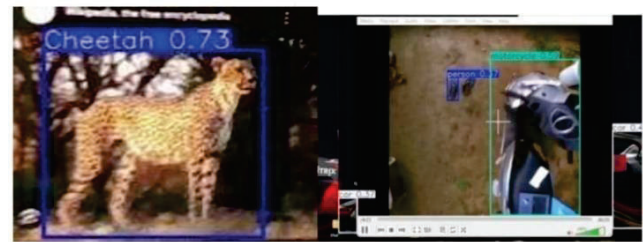


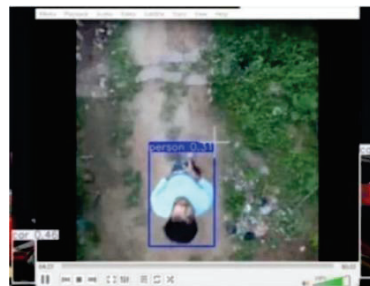
Fig. 5. Drone Result

The testing of the tear-gas system and electric-net mechanism showed that the drone can significantly reduce the need for direct human involvement during difficult crowd-control situations. Instead of officers approaching high-risk areas, the drone can perform critical tasks from a safe distance, improving both officer safety and operational efficiency. This approach not only minimizes physical risk but also allows better control over how and when actions are taken. During trials, the drone consistently reached the required height and position faster than ground teams. This rapid response enabled authorities to monitor crowd behavior from above and gain a clear understanding of the situation without exposing themselves to danger. The availability of a live aerial view also supported quicker and more informed decision-making, helping teams respond effectively to changing conditions. A key observation from the testing was the drone's ability to release tear gas in a controlled and uniform manner. Compared to manual deployment, where distribution can be inconsistent, the drone ensured a steady and precise spread. Since the system was stabilized and remotely operated, operators could adjust the release direction in real time using live video feedback. This helped limit unnecessary exposure



(a)

(c)



(b)



(d)

to non-aggressive individuals and ensured a more targeted and responsible response. The electric-net feature also demonstrated reliable performance, especially in handling isolated aggressive individuals or small groups. The drone was able to deploy the net accurately, temporarily restricting movement without causing serious harm. This reduced the need for direct physical confrontation, which often carries a higher risk of injury for both officers and individuals involved. The net itself was designed to be lightweight, efficient, and safe. It delivered a brief and controlled electric impulse—enough to restrict movement but within safe limits to avoid long-term harm. This balance between effectiveness and safety makes the system suitable for controlled use in sensitive situations. Overall, the results highlight how drone-based systems can make crowd control safer, faster, and more precise. By combining aerial monitoring with controlled intervention tools, the system helps protect both authorities and the public while promoting a more measured and ethical approach. With further refinement and proper regulation, such technologies have strong potential to become an essential part of modern public safety and emergency response operations.

Fig. 6. Detecting animals and other activities

Another key observation was the psychological influence of the drone on crowd behavior. When operated at low to medium altitude, the drone's presence alone encouraged individuals to maintain distance from restricted areas even before any deterrent mechanism was activated, effectively acting as a visible warning system. Meanwhile, the aerial vantage point provided officers with clearer situational awareness, leading to faster and more informed decisionmaking. Performance assessments also indicated stable flight operation despite the added mass of the payload modules, and the platform responded effectively to moderate wind conditions. However, certain limitations were identified: strong wind gusts reduced the accuracy of net deployment, and prolonged hovering increased battery consumption. These constraints suggest the need for further optimization through lighter structural materials and improved power-management solutions. Overall, the results indicate that combining tear-gas dispersion and electric-net restraint technology within a single aerial platform offers a safer and more controlled alternative to conventional riot control techniques. While enhancements remain necessary in areas such as payload stabilization, wind tolerance, and endurance, the findings demonstrate strong potential for such systems to play a significant role in modern non-lethal crowd management applications. The study highlights that, when implemented responsibly, this technology can lower the risk of harm for both officers and civilians while providing authorities with a more precise and effective operational tool.

VI. CONCLUSION

One of the most important advantages of the proposed AeroGuard system is its capacity to lower the danger to human life during hazardous missions. Traditional methods of riot control and suspect capture require officers to operate very close to volatile or hostile situations, which increases the chances of injury, escalation, or operational mistakes. By allowing remote operation, AeroGuard enables agencies to retain complete control from a secure distance, greatly reducing direct exposure to harm. Its capability to reach locations that are difficult or unsafe for ground personnel — such as tight alleyways, rooftops, barricaded areas, and aggressive crowd environments — makes it especially effective in complex urban conditions. Crowdmanagement performance is further improved through the controlled, consistent, and elevated release of tear gas. Unlike ground-level dispersion, which may be blocked by obstacles or negatively influenced by wind patterns, aerial deployment provides broader and more uniform coverage, allowing quicker crowd dispersal while limiting the risk of over-exposure. Because the system is remotely controlled, the timing and quantity of gas emission can be accurately regulated, supporting ethical and responsible use of non-lethal measures. The operational strength of AeroGuard is enhanced by its integrated sensor package, which includes high-resolution cameras, GPS-based navigation, and obstacle-avoidance technology. These tools deliver continuous real-time monitoring and equip operators with up-to-date situational awareness in rapidly changing settings. Such feedback helps decision-makers adjust strategies quickly, improving response precision and lowering the probability of mistakes. In this capacity, the drone functions as an aerial surveillance and observation platform for

command teams during high-pressure incidents. Additionally, the modular architecture of AeroGuard provides remarkable adaptability. Depending on the mission, different payloads — such as searchlights, loudspeakers, or communication relays — may be attached, widening its use beyond policing to disaster management, search-and-rescue missions, and reconnaissance activities. Its rapid-deployment ability further enables agencies to respond swiftly to emergencies while remaining safe.

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