

DRONES AND AUTONOMOUS CARS: ADDRESSING NIGERIA'S INSECURITY ISSUES

ABSTRACT

In Nigeria, a nation with a population exceeding two hundred million, the lack of robust security measures can lead to perilous situations. Here, the focus is on the utilization of drones and autonomous cars as innovative tools for both aerial and terrestrial surveillance. While critically examining existing literature, this paper provides insightful feedback and presents new recommendations. It then delves into design research to visually represent the proposed solutions. The projection suggests that with the adoption of these technologies, Nigeria could experience a significant reduction in insecurity challenges, potentially by 75% by 2033. In conclusion, deploying these advanced surveillance methods is a critical step towards fostering a safer environment for Nigeria.

Keywords: Aerial Surveillance, Autonomous Vehicle, Drone, Insecurity, Platooning.

Author: Njoku, Onyekachi Sylvester

Supervisor: Dr. Chidera Linda Anioke

INTRODUCTION

Insecurity arises in situations marked by exposure to potential harm or threats and a lack of protective measures [1]. Nigeria, with its varied landscapes and bustling urban centers, grapples with intensifying security and surveillance dilemmas. Given the country's vastness and urban intricacies, there's a pressing need for innovative surveillance methods and swift interventions. The emergence of drone surveillance technologies and autonomous vehicles offers a fresh perspective on mitigating these concerns. Various studies have delved into drone surveillance's potential, highlighting their prowess in real-time aerial monitoring and their capacity to efficiently cover large territories, offering invaluable data [2-3]. In parallel, the rise of autonomous vehicles sheds light on their ability to adeptly traverse complex urban terrains, bringing forth capabilities for on-ground surveillance and immediate interventions [4-5].

However, these technological breakthroughs, while promising, also unveil inherent limitations in their direct application to security scenarios. Predominantly, drones are crafted keeping commercial and logistic use cases in mind, possibly sidelining the unique requirements of security surveillance across varied terrains [6]. On the other hand, autonomous vehicles, although brimming with potential, often prioritize passenger safety and seamless traffic navigation over their surveillance functionalities [7].

Here, the research endeavors to explore how drones and autonomous vehicles can be adapted and refined to meet Nigeria's specific security requisites. The endeavor is to rethink and harmonize these technologies, leading to the birth of a holistic, multi-faceted surveillance ecosystem. Through this integration, it seeks to amplify real-time monitoring capabilities and fortify prompt responses to security breaches.

By seamlessly weaving together the attributes of drones and autonomous vehicles, this paper aspires to present a groundbreaking resolution to Nigeria's mounting security quandaries, ushering in an era of enhanced safety and security for its inhabitants.

Yet, there are underlying challenges such as the drone's battery longevity, operational range, and resilience to adverse weather conditions. Autonomous vehicles, equipped

with cutting-edge sensors, cameras, and AI-driven navigation tools, hold potential in security patrolling and swift emergency reactions. However, technical hindrances include maneuvering through Nigeria's multifaceted landscapes and ensuring uninterrupted communication for optimal control. While the potential of both technologies is undeniable, they do have distinct technical nuances to address.

Aim and Objectives:

The central thrust of this research is to scrutinize the potential of drones and autonomous vehicles in strengthening security measures and curtailing Nigeria's escalating insecurity issues.

Theoretical Analysis:

This paper aims to design one drone and one autonomous vehicle which will be referred to as POL_DRONE_1.01 and POL_CAR_1.01 respectively.

- POL_DRONE_1.01

A typical Drone Architecture is shown in Fig. 1 below

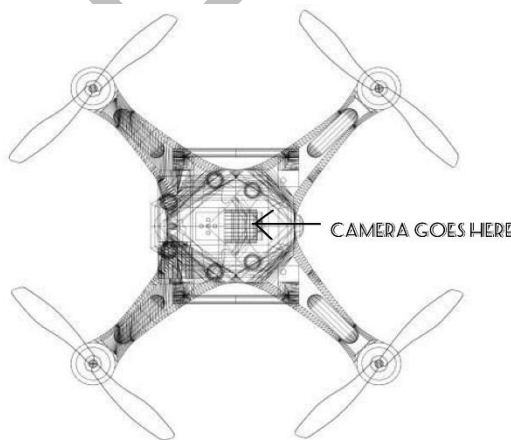


Fig. 1: A Drone Architecture (Reproduced from [8])

[9] A drone, also known as an Unmanned Aerial Vehicle (UAV) and illustrated in Fig. 1, is an aircraft that operates without a human pilot or any personnel onboard. For optimal surveillance capabilities in Nigeria, this design emphasizes on drone platooning and the integration of artificial intelligence for control.

In this research, the idea is for the drone cameras to be bottom mounted, providing an aerial view of areas of interest which may include kidnap hideouts. An exemplar aerial surveillance image is depicted in Fig. 2. In this context, it's suggested that discerning anomalies, like fire outbreaks in vegetative zones or atypical human-made paths and unregistered movements, can empower the drone to notify security entities about potential security breaches, such as kidnapping incidents. This drone's capability stems from machine learning algorithms, which this paper will touch upon briefly.

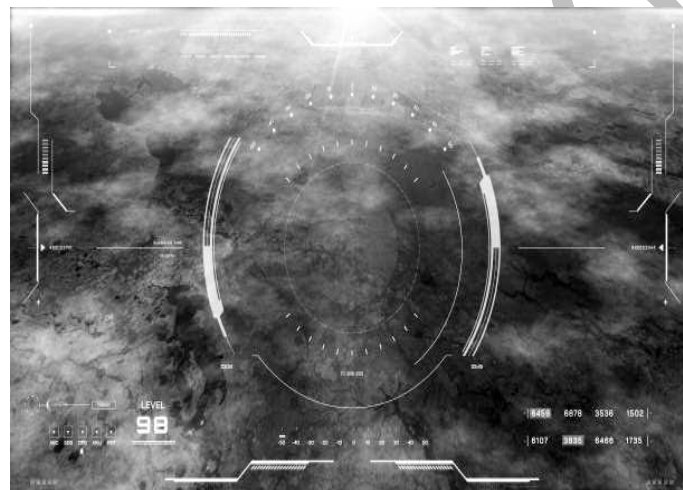


Fig. 2: An exemplar aerial surveillance image (source: [10])

The rollout of these drones will adhere to a DFIF approach – Data collection, Flight, Investigation, and Feedback.

Information will be gathered from citizens and processed using a Q-learning machine learning algorithm [11] to optimally position the drones in anticipated attack zones.

The Q-learning equation is given by:

$$Q(S_k, A_k) = Q(S_k, A_k) + \alpha[R_{k+1} + \gamma \max_a Q(S_{k+1}, a) - Q(S_k, A_k)] \quad (1)[11]$$

Where:

- $Q(S_k, A_k)$ represents the Q-function
- S_k represents the current state of the agent
- A_k represents the action the agent chooses

- α represents the learning rate
- R_k represents the reward
- S_{k+1} represents the next state after the action
- A_{k+1} represents the next action that the agent choose
- R_{k+1} represents the reward for the next action
- $\gamma \max_a$ represents the maximum discount factor

However, the intricacies of the Q-learning algorithm are not explored in this study.

The drone undergoes deployment for its flight phase. At this stage, it navigates areas delineated by the Q-learning algorithm. To ensure comprehensive investigation of the designated region, the drone follows a predetermined pattern. This pattern is depicted in Fig. 3.

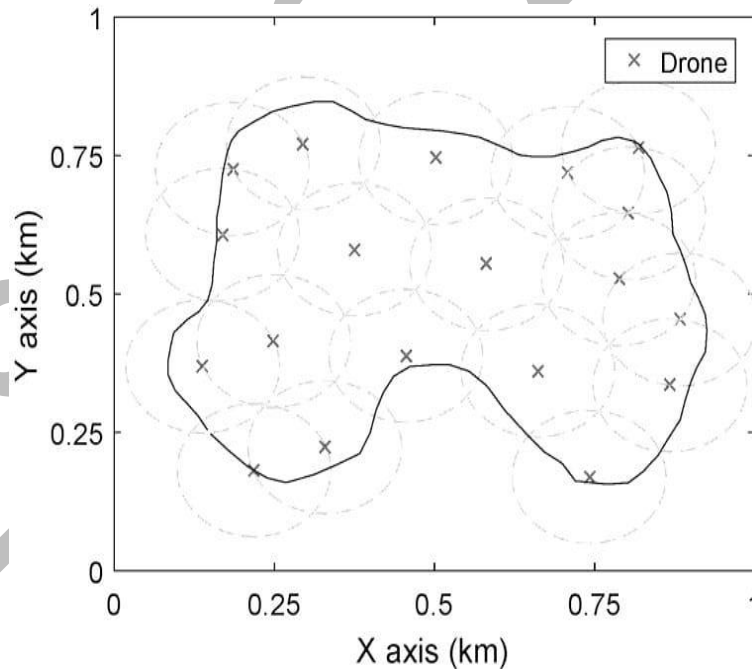


Fig. 3: Drone flight pattern (Source: [12])

Once the drone achieves lift-off, the subsequent design phase focuses on accurate anomaly detection. In the context of this study, POL_DRONE_1.01 is assumed to be equipped with machine learning algorithms tailored for flight path anomaly detection. Upon identifying any irregularities, as depicted in Fig. 4, POL_DRONE_1.01 functions similarly to a radio, emitting signals to

satellites. These satellites then relay this data to security agencies for appropriate intervention. The communication framework is illustrated in the block diagram of Fig. 5.

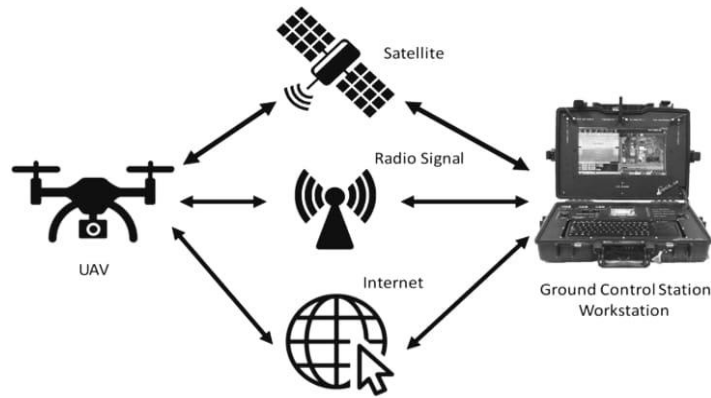


Fig. 4: Drone – Satellite communication process (Reproduced from [13])

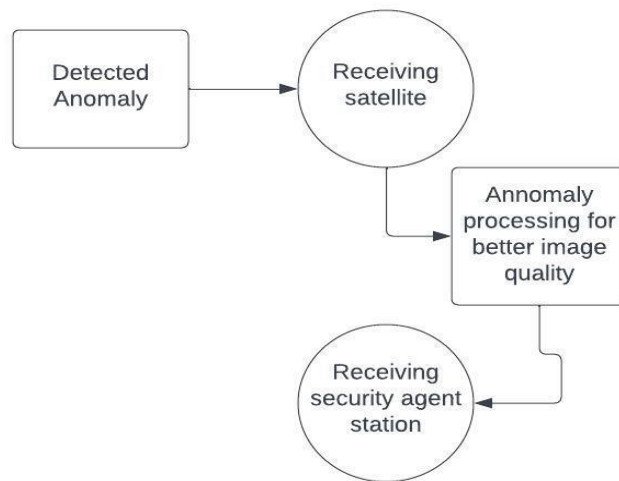


Fig. 5: Block Diagram of Satellite – Station communication process

This provides a comprehensive analysis of what we expect from POL_DRONE_1.01.

- POL_CAR_1.01

The technologies in an autonomous vehicle are shown in Fig. 6 below.

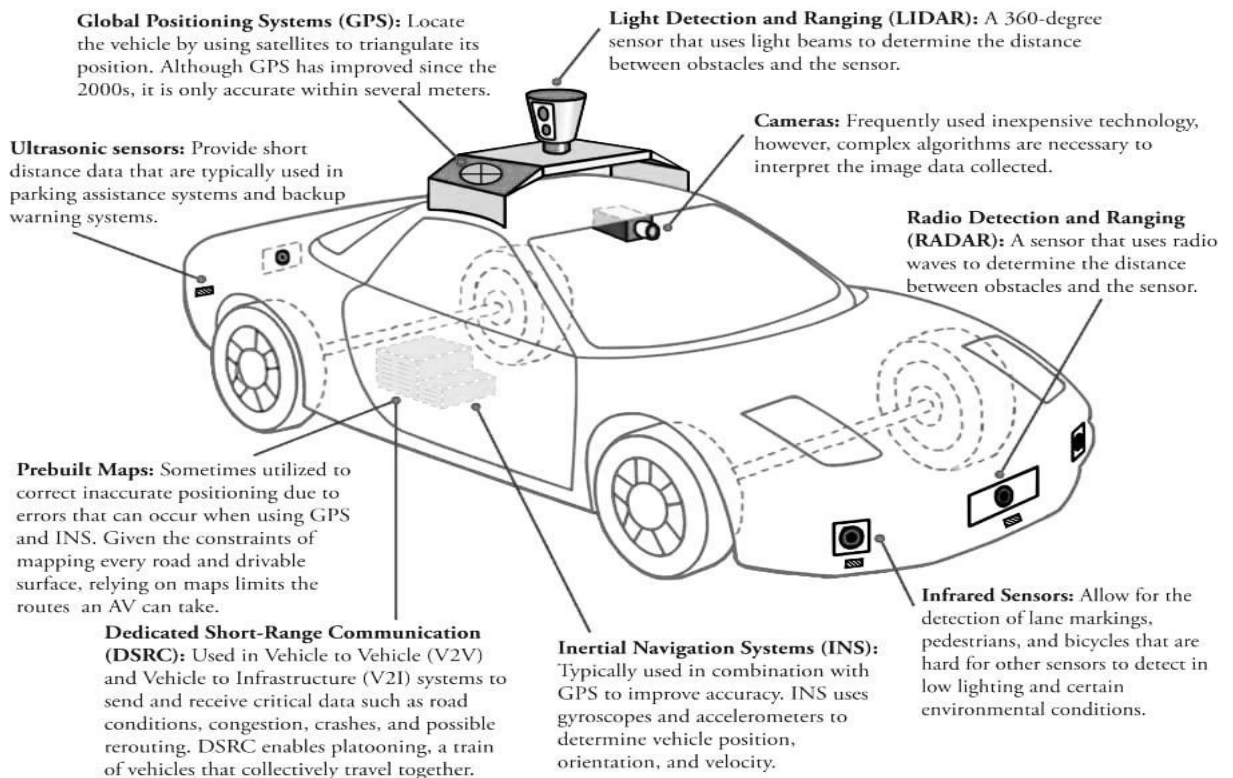


Fig. 6: Autonomous vehicle technologies (Reproduced from [14])

POL_CAR_1.01 essentially needs three key components: 'vision', 'intelligence', and 'action', represented by sensors, processing units, and actuators, correspondingly. These parts convert a conventional vehicle, bestowing upon it the ability to observe, analyze, and respond much like a human driver. In POL_CAR_1.01's blueprint, we concentrate on two main aspects: the complex yet essential task of strategically positioning sensors, and a typical autonomous control system serving as the actuator to handle the steering, accelerator and brake pedals, as well as gear shifts. In this research, akin to the design principles of POL_DRONE_1.01, it's posited that POL_CAR_1.01 is integrated with machine learning algorithms customized for detecting anomalies in its driving path. While POL_DRONE_1.01 is envisioned to operate in a reconnaissance capacity, POL_CAR_1.01 is designed to actively engage with and counteract violent crime

perpetrators. To this end, POL_CAR_1.01 is outfitted with specialized equipment, either to de-escalate situations or neutralize threats.

- **Sensor plan**

In this section, we will explore the range of sensors that can be installed on a vehicle, covering a vast array of the typical types found in the market. These include camera-based sensors, millimeter-wave RADAR, ultrasonic sensors, LiDAR, GPS, and inertial sensors. Each type of sensor differs significantly in various aspects, such as range, distance, functionality, performance, etc. Choosing the right sensor setup involves a delicate balancing act between functionality, range, and cost. If not carefully considered, serious mishaps may occur due to unfavorable weather conditions or sensor blind spots, among other factors. With this in mind, let's delve into an introductory overview of some commonly used sensors.

Cameras provide different field of view (FOV) ranges and distances, thanks to the variety of lenses available. Commonly, a 16 mm focal length lens is employed for frontal detection to strike a balance between distance and FOV. If a larger FOV is of prime importance, a 6 mm lens or even a fish-eye lens can be utilized. It's important to remember, though, that this expanded FOV comes at the expense of detection distance due to lens distortion.

LiDAR sensors generate a direct 3D representation of the environment using point clouds, offering a level of stability cameras can't match due to their immunity to light variation. However, their usage is limited during heavy rain, and they generally cost about ten times more than a camera.

Millimeter-wave RADAR sensors are typically used in tandem with cameras to detect moving metallic objects. Even though these sensors have lower sensitivity, the trade-off is a resolution that increases as range decreases, making it an ideal sensor for range and distance detection. This is essential in distinguishing between victims and suspects. Plus, they function well under all weather conditions due to their excellent penetration capabilities.

Ultrasonic sensors are commonplace on most modern vehicles, primarily used for low-speed parking maneuvers due to their ability to detect short distances,

typically under 5 meters. Being the most cost-effective sensor type, they are widely used despite their limited range.

Now, let's look at the desired sensor plan, illustrated in Fig. 7.



Fig. 7: Sensor ranges and distances. Different shades stand for different sensors. Source: [15].

This configuration includes two standard cameras, three millimeter-wave RADARs, one 360-degree camera, and a twelve-unit ultrasonic sensor.

- Control System

Here, we treat POL_CAR_1.01 as a two-wheeled system commonly referred to as the “bicycle model” [18] illustrated in Fig. 8.

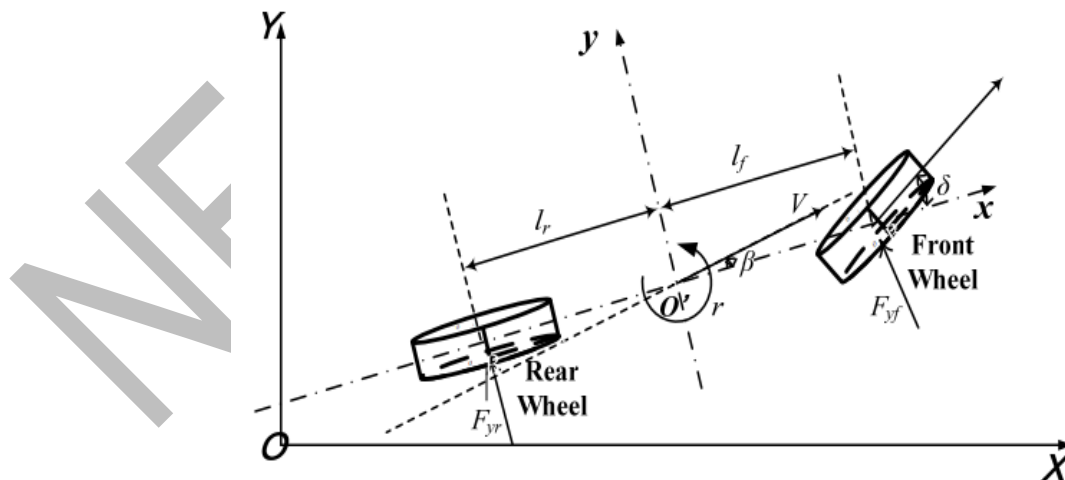


Fig. 8: Bicycle model (Reproduced from [16])

A simplified two-degree-of-freedom model can describe the vehicle's movement with certain assumptions:

1. Considering the vehicle moves on an even surface without vertical angle changes due to road imperfections, it's feasible to overlook the vertical forces and related dynamic interactions.
2. The entire vehicle, including its suspension system, is treated as a solid structure.
3. Inputs are directly applied to the tire, disregarding the steering mechanism. Alternatively, assuming a solid steering system that transmits input to the pivoting tires through the steering wheel at a consistent ratio.
4. Aerodynamic forces are not taken into account.
5. The vehicle only experiences minor deviations from its balance point. This indicates that the front wheel's input angle remains small, ensuring the motion equations' linearity.

Further analysis of the bicycle model can be seen in [16].

RESULTS

This paper projects a 75% reduction in violent crimes bordering assault, murder, armed robbery and kidnappings from the year 2023 to the year 2033. To make comprehensive projections, this paper bases its projections on a combination of historical data regarding insecurity incidents in Nigeria in 2018 [17] [18] and current trends in drone and autonomous car technology. To achieve graphical projections, this paper adopts Monte Carlo simulation. This simulation is run using Python programming language. The graphical representation is shown in Fig. 9.

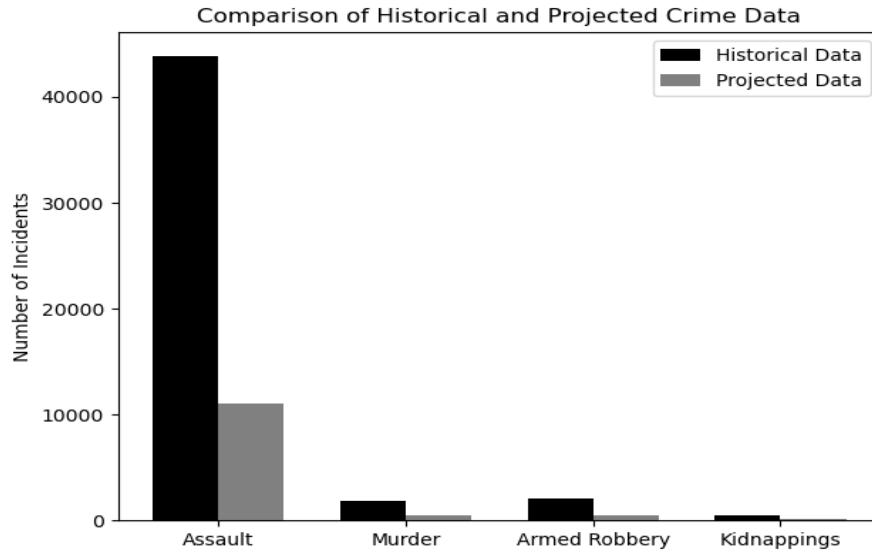


Fig. 9: Projected result of study

DISCUSSION:

In the exploration of drones and autonomous cars as potential solutions to Nigeria's escalating insecurity issues, this paper has highlighted several pivotal experimental findings. Central among these is the capability of drones to offer real-time aerial surveillance across extensive territories. This capability is notably significant when compared with traditional surveillance methods, emphasizing the potential of drones to provide instant feedback and vastly improve surveillance efficacy.

Drawing from established research, there is an emerging consensus regarding the effectiveness of drones in diverse security contexts around the world. Studies consistently highlight the transformative role of drones in border security and counter-terrorism efforts in numerous regions. In a parallel vein, autonomous cars, outfitted with state-of-the-art sensors and AI-driven decision mechanisms, have demonstrated their proficiency in navigating intricate urban terrains, serving dual purposes of transportation and surveillance.

Trends pointing towards the future of security underscore the shift towards a more cohesive strategy, amalgamating aerial and terrestrial surveillance. The interplay between drones and autonomous cars, as delineated in this paper, hints at the advent of a collaborative security framework. Such a model aims not just to deter threats but to also facilitate real-time countermeasures.

The implications of the results derived from this research are in complete harmony with the overarching aims and objectives of the study. Employed methodologies, ranging from AI integrations to real-time data analytics, manifest their potential in enhancing the functionalities of both drones and autonomous vehicles in a security context. By adapting these technologies to Nigeria's unique geographical and security nuances, this paper underscores the adaptability and relevance of modern technological solutions in confronting prevailing societal challenges.

In summary, the myriad of security challenges that Nigeria grapples with may be intricate and entrenched; however, the potential of drones and autonomous cars in alleviating these concerns, as emphasized in this paper, is undeniably significant. The

integration of these avant-garde technologies into Nigeria's security blueprint not only offers a contemporary remedy but also provides a visionary approach, paving the way for a more secure Nigeria in the foreseeable future.

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CONCLUSION AND RECOMMENDATIONS

Proper implementation of POL_DRONE_1.01 and POL_CAR_1.01 and strict adherence to guidelines will see an astronomical reduction in the rate of violent crimes in our country. The beauty of this technology is its cost-efficiency, dependent on citizen provided information and automation.

The idea is for POL_DRONE_1.01 to be deployed in areas that are not motorable like hide-outs and train tracks while POL_CAR_1.01 will be deployed in and around school premises and on express roads. The surveillance POL_DRONE_1.01 and POL_CAR_1.01 provide will be backed-up in real time to an official server that will be accessible to security operatives to carry out further operations if necessary.

Nigeria is the only country we have and we must all come together to find lasting solutions to our problems. Any country with security issues is a country doomed to be retrogressive. I therefore urge our government to adopt this idea for the security of all our citizens.

REFERENCES

- [1] "Insecurity – Wikipedia," [Online]. Available: <https://www.google.com/search?q=insecurity&oq=insecurity+&aqs=chrome..69i57j69i60l2j69i59l2joi271l3j69i60j69i61.1452joj7&client=ms-android-transsion&sourceid=chrome-mobile&ie=UTF-8>
- [2] X. Dai and M. Nagahara, "Platooning control of drones with real-time deep learning object detection," *Adv. Robot.*, 2022, doi: 10.1080/01691864.2022.2119888.
- [3] S. Richhariya, K. Wanaskar, and S. Shrivastava, "Surveillance Drone, Cloud, and AI Services," in *IEEE MobileCloud 2023*, Athens, Greece, 2023. [Online]. Available: https://www.researchgate.net/publication/371469919_Surveillance_Drone_Cloud_and_AI_Services
- [4] W. Zong, C. Zhang, Z. Wang, J. Zhu, and Q. Chen, (Senior Member, IEEE), "Architecture Design and Implementation of an Autonomous Vehicle," *IEEE Access*, May 2018. [Online]. Available: 10.1109/ACCESS.2018.2828260.
- [5] M. Hasanujjaman, M. Z. Chowdhury, and Y. M. Jang, "Sensor Fusion in Autonomous Vehicle with Traffic Surveillance Camera System: Detection, Localization, and AI Networking," *Sensors*, vol. 23, pp. 3335, Mar. 2023. [Online]. Available: <https://doi.org/10.3390/s23063335>.
- [6] M. W. Muricho and C. O. Mogaka, "Drone technology and performance of retail logistics," *J. Sustain. Dev. Transp. Logist.*, vol. 7, no. 1, 2022, doi: 10.14254/jsdtl.2022.7-1.6. [Online]. Available: <https://jsdtl.sciview.net>
- [7] T. F. Abiodun, "PUBLIC SUPPORT AND PROSPECTS OF DRONES OR UNMANNED AERIAL VEHICLES (UAVs) TECHNOLOGIES FOR EFFECTIVE TRANSPORT AND LOGISTICS DELIVERY IN NIGERIA," Feb. 2021. [Online]. Available: <https://doi.org/10.46654/ij.24889849.e7126>.

- [8] "Drone Concept Architect Blueprint," iStock. [Online]. Available: <https://www.istockphoto.com/photo/drone-concept-architect-blueprint-isolated-gm982566246-266801543>. [Accessed: 10-Aug-2023].
- [9] "Unmanned aerial vehicle - Wikipedia," [Online]. Available: https://en.m.wikipedia.org/wiki/Unmanned_aerial_vehicle
- [10] "Aerial Surveillance Pictures, Images and Stock Photos," iStock. [Online]. Available: <https://images.app.goo.gl/hkNRrMZmTStXf2rh6>. [Accessed: 10- Aug-2023].
- [11] A. Paglialunga, "Machine Learning Algorithms for Drones Cooperative Navigation," Corso di Laurea Triennale in Ingegneria Elettronica, ATER STUDIORUM - UNIVERSITA DI BOLOGNA, CAMPUS DI CESENA, SCUOLA DI INGEGNERIA E ARCHITETTURA, 2020-2021. Supervised by Chiar.mo Prof. Ing. D. Dardari and Dott. Ing. A. Guerra.
- [12] A. V. Savkin and H. Huang, "Asymptotically Optimal Deployment of Drones for Surveillance and Monitoring," **Sensors**, vol. 19, no. 9, p. 2068, May 2019. [Online]. Available: <https://doi.org/10.3390/s19092068>.
- [13] M. Aljehani, M. Inoue, A. Watanabe, T. Yokemura, F. Ogyu, and H. Iida, "UAV communication system integrated into network traversal with mobility," in **SN Applied Sciences**, vol. 2, no. 1057, May 2020. [Online]. Available: <https://link.springer.com/article/10.1007/s42452-020-2749-5>. [Accessed: 13 August 2023].
- [14] A. K. Sangaiah, S. C. Pandey, J. J. P. C. Rodrigues, Z. Alazawi and M. Guizani, "Efficient Electric Vehicle Charging Management for Smart Cities," in *Sensors*, vol. 21, no. 16, pp. 1-22, 2021. Available: <https://www.mdpi.com/1424-8220/21/16/5397>.
- [15] J. Al-Jaroodi, N. Mohamed, I. Jawhar, S. Zhang and Z. Wu, "Architecture Design and Implementation of an Autonomous Vehicle," ResearchGate, 2018. [Online]. Available: https://www.researchgate.net/publication/324629714_Architecture_Design_and_Implementation_of_an_Autonomous_Vehicle.

- [16] P. Zhao, J. Chen, Y. Song, X. Tao, T. Xu, and T. Mei, "Design of a Control System for an Autonomous Vehicle Based on Adaptive-PID," *International Journal of Advanced Robotic Systems*, Apr. 2012, doi: 10.5772/51314.
- [17] P. E. Oguntunde, O. O. Ojo, H. I. Okagbue, and O. A. Oguntunde, "Analysis of selected crime data in Nigeria," *Data Brief*, vol. 19, pp. 1242–1249, Aug. 2018. [Online]. Available: <https://doi.org/10.1016/j.dib.2018.05.143>
- [18] Statista, "Number of people kidnapped in terrorist attacks in Nigeria from 2017 to 2019," Statista. [Online]. Available: <https://www.statista.com/statistics/1198407/people-kidnapped-in-terrorist-attacks-in-nigeria/>. [Accessed: 9 Aug. 2023].