IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 21, Issue 2 Ser. 1 (Mar. – Apr. 2024), PP 35-41
www.iosrjournals.org

Advancement In Drone Technology Integrated With Artificial Intelligence And Lidar Sensor

Zafeer Ahmed Qadeer [1], Mohammed Akram [2]
[1,2] B.E. Mechanical Undergraduate, Muffakham Jah College Engineering & Technology, Hyderabad, Telangana, India 500034

Abstract:
In an attempt to better understand how AI, LiDAR, and drones work together, the study paper examines how these technologies might improve data analysis, navigation, mapping, and object detection. The goal of the paper is to provide a more thorough comprehension of the revolutionary influence on autonomous systems. It presents the basic ideas of how to integrate knowledge of their environment with integration, leading to an advancement into the technology world. Firstly, a thorough analysis of the material already in existence offers a more profound comprehension of the current state of affairs, encompassing the historical progression and pivotal discoveries in every technology. The practical consequences of integrating AI and LiDAR in systems are then demonstrated through a thorough examination of case studies and real-world applications. This research highlights the technological difficulties of the integration by looking at the underlying algorithms that enable autonomous navigation, object detection, and data processing.
Keywords - *Artificial Intelligence, LiDAR, Unmanned Aerial vehicles (UAVs), Drone, Machine Learning, Data analysis, Mapping, Object detection, Object tracking.*

Date of Submission: 25-03-2024 Date of Acceptance: 05-04-2024

I. Introduction

Over the past decade, the advancement of Unmanned Aerial Vehicles (UAVs) has been remarkable, extending far beyond their original purpose in both civilian and military settings. While initially utilised for tasks such as rescue missions, surveillance, and mapping, UAVs have now become crucial in emergency evacuation efforts and the creation of innovative smart cities. These versatile aircraft have also played a vital role in civil construction projects, efficient real estate management, and monitoring climate patterns. Drones possess distinct classifications determined by factors such as Size, Weight, and Power (SWAP), which significantly impact their flight duration, altitude range, and communication proficiency. The integration of High Altitude Platforms (HAP) elevates communication abilities, leading to a crucial strategic decision between altitude platforms in order to maximise storage and coverage. Although drone advancement has been swift, a thorough evaluation of their evolution and potential remains elusive. The potential for UAV applications to sky rocket from 2010 to 2022 is captured with an emphasis on the integration of cutting-edge fifth-generation (5G) connectivity. This leap in technology enhances the performance of UAVs in multiple areas, including manoeuvrability, scalability, and communication. It's no surprise that the UAV application market is predicted to soar beyond $20 billion in 2022, showcasing its significant impact on a global scale. [1]

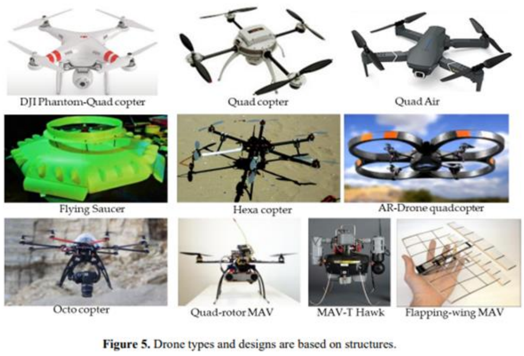

Fig : Drone Types and designs based on structures
(Image Courtsey Reviews on Design and Development of Unmanned Aerial Vehicle (Drone) for Different Applications Journal of Mechanical Engineering Research and Developments)

Moreover, the advancement of drones with Light Detection and Ranging (LiDAR) technology is transforming the way construction projects are surveyed, thanks to the precise data points they provide. As the use of unmanned aerial vehicles (UAVs) continues to be explored, their versatility and ease of deployment stand out, making them suitable for tasks such as wireless connectivity, weather forecasting, and disaster response. However, challenges remain, including susceptibility to adverse weather conditions and limited battery life. To overcome these obstacles, Artificial Intelligence (AI) and Machine Learning (ML) are being leveraged. By using sensor data, AI-assisted UAVs can excel at managing resources and avoiding obstacles, promising to revolutionise a multitude of applications.[2]

II. Methodology

The integration of AI in UAV networks has ushered in innovative solutions for a diverse range of challenges. To encapsulate the key open issues identified earlier in the context of UAV-based problems, we first focus on Machine Learning (ML). The proposals include the exploration of lightweight ML algorithms suitable for on-board processing, the design of hybrid UAV detection solutions leveraging various data types such as sound, image, and radar, and a concerted effort towards expanding and unifying UAV drone regulations globally. These initiatives aim to enhance the efficiency and intelligence of UAV networks while addressing crucial aspects of machine learning and regulatory frameworks.

Machine Learning (ML) has become a prominent component of Artificial Intelligence (AI), leveraging vast datasets and powerful computing to achieve accurate task execution based on past experiences. This survey explores the application of ML in Unmanned Aerial Vehicles (UAVs) and distinguishes between supervised and unsupervised learning, emphasizing their relevance in solving UAV-related challenges.

- **Supervised Learning:** Supervised learning involves labelled data, where each entry is associated with a ground-truth value. For example, predicting the price of a UAV based on its characteristics requires a training dataset with labelled UAV characteristics and prices. The data is divided into a training set and a test set, used for learning the relationship between input and output and validating model accuracy. Supervised problems include regression (continuous output) and classification (discrete values indicating class membership). Notable algorithms include Support Vector Machine (SVM), decision trees, linear regression, logistic regression, Multi-Layer Perceptron (MLP), Convolutional Neural Networks (CNNs), and Recurrent Neural Networks (RNNs).[12]
- **Unsupervised Learning:** Unlike supervised learning, unsupervised learning works with unlabeled data, seeking underlying structures or hidden patterns. Tasks include clustering, dimensionality reduction, and data generation. Clustering algorithms like K-means, Gaussian Mixture Modelling (GMM), DBSCAN, and agglomerative clustering are popular. Dimensionality reduction techniques, such as autoencoders (AEs) and principal component analysis (PCA), transform data into lower-dimensional representations. Generative Adversarial Networks (GANs) use two neural networks to generate synthetic data instances, widely applied in image, video, and voice generation. [13]

Table 1: AI and ML Algorithms uses in UAV [14]

Applications	Algorithms	Advantages
Object Tracking	Visual Object Tracking Algorithms	1. Enables the drone to follow and monitor specific targets. 2. Essential for surveillance, tracking moving objects, and maintaining a constant focus on a subject 3. Enhances situational awareness.
Object Mapping	Simultaneous Localization and Mapping (SLAM) Algorithms	1. Creates a dynamic map of the drone's environment. 2. Facilitates autonomous navigation and obstacle avoidance. 3. Useful in applications such as 3D mapping, exploration, and inspections.
Voice Control	Speech Recognition Algorithms	1. Hands-free drone operation. 2. Enables intuitive and natural communication with the drone. 3. Enhances user experience, especially in applications like search and rescue.

Object Tracking:

Object tracking in drones is a critical feature enabling autonomous monitoring of specific targets. It finds applications in surveillance, search and rescue, filming, and environmental monitoring. The Kernelized

Correlation Filter (KCF) is a popular algorithm for object tracking in drones. KCF efficiently initializes, tracks, adapts to changes in appearance, handles scale and rotation, and operates in real-time, making it suitable for various drone-based tracking applications.

- Initialization: KCF begins by selecting the target object in the first frame, modelling its appearance using a kernelized correlation filter.
- Tracking: Subsequent frames involve searching for the target by correlating the learned filter with the current frame content in the frequency domain.
- Adaptation: Continuous updates to the filter based on the target's appearance ensure robustness against changes like lighting, occlusions, or pose variations.
- Scale and Rotation Handling: KCF efficiently manages variations in size and orientation of the tracked object.
- Real-time Operation: KCF's computational efficiency allows it to operate in real-time, addressing applications with low-latency requirements, such as drone-based tracking.

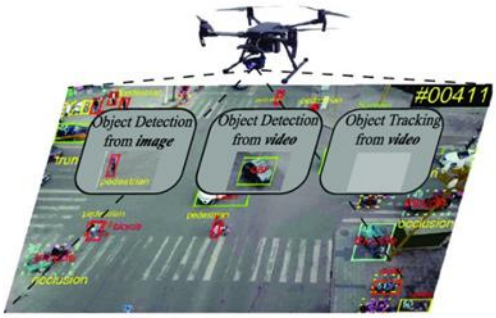

Fig : Object Capture by Drones (Image Courtesy : Deep Learning for UAV-based Object Detection and Tracking: A Survey)

Object Mapping:

Drone mapping, or aerial surveying, uses drones and photogrammetry software to create 2D orthomosaics and 3D models of areas. In the context of drones, object mapping involves creating a representation or map of the environment using data collected by sensors such as cameras or LiDAR. The Simultaneous Localization and Mapping (SLAM) algorithm, including FastSLAM, is commonly employed for object mapping in dynamic environments.

- Landmark Initialization: The drone starts with an initial estimate of its location and landmark positions.
- Sensor Data Collection: The drone collects sensor data from its onboard cameras or other sensors.
- Feature Extraction: Features (landmarks) are extracted from sensor data, such as visual points or edges.
- Association and Data Association: The algorithm associates extracted features with existing landmarks, determining whether they correspond to known landmarks or represent new ones.
- Update Landmark Positions: Positions of landmarks in the map are updated based on associations.
- Update Drone's Pose: The drone's estimated pose is updated based on newly observed features.
- Mapping and Localization: The process repeats as the drone moves, continuously updating the map and refining its estimate of its own pose.

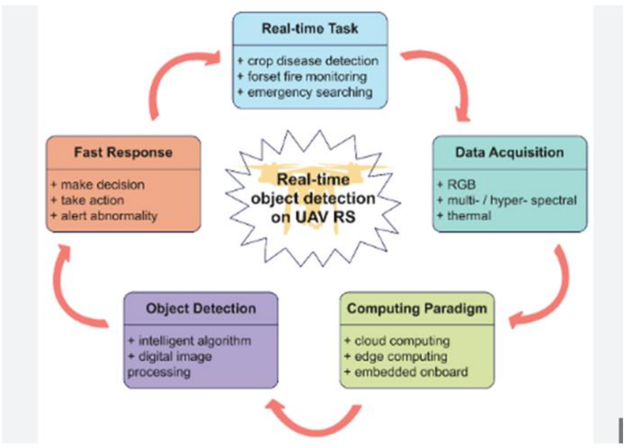

Fig : Object Mapping

Voice Controlled in Drones:

Voice control in drones enables users to command various operations using spoken instructions, enhancing hands-free operation. The use of speech recognition algorithms, such as the Hidden Markov Model (HMM), facilitates this capability.

- Speech Input: The drone's system receives audio input from a microphone, capturing the user's spoken command.
- Feature Extraction: Audio signals are processed to extract features representing the speech.
- Model Training: The system is trained using labelled audio data associating spoken commands with specific drone actions.
- HMM Construction: Hidden Markov Models are constructed for each command based on training data.
- Speech Recognition: Trained HMMs recognize spoken words or phrases, calculating likelihoods for each possible command model.
- Command Interpretation: The recognized command is interpreted and translated into instructions for the drone.
- Drone Control: The interpreted command is sent to the drone's control system, enabling execution of the desired action.

Advancement

The Advancement in Drone Technology integrated with Artificial Intelligence and LiDAR Sensor can be used in disastrous situations with the addition of AI Algorithms listed above and key features in Drone technology. The increasing frequency and severity of disasters necessitate advanced technologies for efficient hazard monitoring and response. A novel approach integrating web scraping and autonomous drones for real-time data collection and analysis in disaster-stricken areas. The system uses web scraping algorithms to extract real-time hazard information from reliable sources, triggering the deployment of autonomous drones equipped with sensors, GPS, and imaging technologies. The drones navigate through hazardous environments, collecting comprehensive data for timely and informed disaster response. The collected information is transmitted wirelessly via satellite connection to a centralized system for seamless communication and rapid analysis..

Web Scraping for Hazard Information:

Web scraping is introduced as a potent tool for collecting real-time data, with a focus on algorithmic details. The paper delves into the implementation of regular expressions for precise data extraction, the use of XPath and CSS selectors for HTML structure navigation, and the application of HTML parsing libraries such as Beautiful Soup and lxml. Headless browsers, APIs, and rate-limiting strategies are discussed, ensuring ethical and efficient data retrieval. The inclusion of scraping frameworks like Scrapy is highlighted for streamlined web scraping processes.

Web scraping involves extracting information from websites, and to ensure timely and accurate data retrieval, you can consider the following algorithms and techniques:

1. Regular Expressions (RegEx): Use regular expressions to define patterns for the data you want to extract. This ensures accuracy by specifying the exact format of the information you're looking for.
2. XPath and CSS Selectors: These are powerful tools for navigating the HTML structure of a webpage. They help pinpoint specific elements, ensuring that you extract the right data from the right location.
3. HTML Parsing Libraries:
   - Beautiful Soup, a Python library, is created to extract data from HTML and XML files. It offers Pythonic expressions for navigating, searching, and altering the parse tree with ease.
   - lxml: A faster HTML and XML parsing library for Python, which also supports XPath.
4. Headless Browsers: Utilize headless browsers like Puppeteer (for JavaScript-heavy websites) to simulate real user interactions. This is particularly useful when websites use dynamic content loaded through JavaScript.
5. APIs (if available): Some websites offer APIs for accessing data programmatically. If available, using an API can provide a more structured and reliable way to retrieve information.
6. Rate Limiting and Throttling: Implement mechanisms to control the rate at which you send requests to a website. This ensures you don't overload the server, which could result in your IP being blocked.
7. Error Handling: Implement robust error handling to manage situations where the website's structure changes or the data format is modified. This helps maintain the accuracy of your data retrieval process.
8. Scraping Frameworks: Consider using web scraping frameworks like Scrapy (Python) or BeautifulSoup, which provide built-in functionalities for handling common scraping tasks.

Communication with Drone Center:

The research underscores the development of a robust communication protocol between drones and the nearest drone center. Communication technologies such as IoT and 5G are leveraged for seamless data transmission, establishing a centralized system for receiving and processing incoming hazard alerts. The paper outlines the utilization of Hidden Markov Model (HMM) for voice-controlled commands, enhancing user experience and facilitating hands-free drone operation.

Drone Deployment and Information Collection:

The integration of sensors, GPS, and imaging technologies on autonomous drones is detailed, incorporating algorithms such as Kernelized Correlation Filter (KCF) for object tracking. The paper introduces the application of Simultaneous Localization and Mapping (SLAM) for object mapping, elucidating its relevance in dynamic environments. Autonomous navigation systems are implemented, featuring waypoint navigation, obstacle avoidance through lidar sensors, and path planning algorithms. Machine learning models enhance navigation decisions based on real-time data, ensuring adaptability to changing environments. The research emphasizes real-time data processing and secure communication protocols between the drone and the control center.

Implementing autonomous navigation systems for efficient deployment and information gathering in drones involves integrating various technologies and algorithms.Here is a summary of the critical elements::

1. GPS and IMU Integration:

The drone benefits from accurate positioning information through the utilization of Global Positioning System (GPS) modules. Additionally, Inertial Measurement Unit (IMU) sensors are incorporated to measure and maintain the drone's orientation and velocity.

2. Waypoint Navigation:
- The drone is equipped with algorithms facilitating waypoint navigation, enabling it to follow a predefined path or set of coordinates.
- GPS waypoints play a crucial role in guiding the drone through a designated route, ensuring systematic information gathering.

3. Obstacle Avoidance:
- The drone's path is safeguarded by the integration of sensors such as lidar or ultrasonic sensors, detecting obstacles in its trajectory.
- Sophisticated obstacle avoidance algorithms empower the drone to autonomously navigate around impediments, ensuring safe deployment.

4. Path Planning:
- Path planning algorithms are employed to optimize the drone's route, factoring in environmental constraints and mission objectives.
- Considerations such as terrain, weather conditions, and urgency contribute to planning the optimal path for the drone.

5. Machine Learning for Navigation:
- Machine learning models enhance the drone's navigation decisions by leveraging real-time data.
- These models are trained to adapt to changing environments, augmenting decision-making capabilities during deployment.

6. Real-time Data Processing:
- Algorithms for real-time processing of sensor data are developed, enabling the drone to make immediate navigation adjustments based on environmental cues.
- Efficient data transmission between the drone and the control center is ensured to maintain low latency in decision-making.[15]

7. Redundancy and Fail-Safe Mechanisms:
- Redundancy is incorporated into the navigation system to ensure reliability in the event of sensor or component failures.
- Fail-safe mechanisms, including return-to-home protocols, are implemented to address unexpected situations and enhance overall system resilience.

9. Communication Protocols:
- Robust communication protocols are established between the drone and the control centre, facilitating continuous monitoring and remote control capabilities if needed.

- Secure and reliable communication channels are employed to transmit navigation commands and receive real-time updates seamlessly.

Implementing these elements collectively contributes to the development of a robust autonomous navigation system, ensuring efficient deployment and effective information gathering by the drone in hazardous situations.

III. Discussion

The integration of Artificial Intelligence (AI) and Machine Learning (ML) with Unmanned Aerial Vehicles (UAVs) has brought about a revolutionary shift in what is possible, propelling various industries forward. Through a thorough examination of existing literature, it is evident that these cutting-edge technologies have the potential to greatly enhance operational versatility and remote monitoring capabilities. By harnessing the power of AI and ML, UAVs have produced swift and dependable results, expanding their usage in urban planning, military defense, farming, and mining. However, there are still challenges and unresolved issues to address, such as the need for lightweight ML algorithms, hybrid UAV detection systems, and a unified approach to global UAV regulations.

The conversation explores the practical uses of UAV technologies powered by AI, highlighting the importance of three key features: object tracking, object mapping, and voice control. The advanced algorithms like Kernelized Correlation Filter (KCF), object tracking enables independent tracking of specific targets, makes it crucial for tasks such as surveillance, search and rescue, and environmental monitoring. Additionally, Simultaneous Localization and Mapping (SLAM) algorithms are essential for object mapping, allowing drones to dynamically map their surroundings for tasks like 3D mapping and inspections. Finally, with the help of speech recognition algorithms like Hidden Markov Model (HMM), voice control enhances user experience and allows for hands-free operation of drones.

In the methodology section, it explains the depth of the cutting-edge achievements within drone technology, particularly in situations involving disaster response. By implementing web scraping and autonomous drones, we have created a compelling method for gathering and analyzing live data in areas affected by disasters. Our system employs web scraping algorithms to swiftly extract vital hazard information, which then triggers the deployment of autonomous drones outfitted with advanced sensors, GPS capabilities, and imaging technologies. Thanks to a smooth satellite connection to a centralized system, we are able to coordinate an efficient and informed disaster response in a timely manner.

IV. Conclusion

- Ultimately, the research paper illuminates the progress and practical uses of UAV technology through the incorporation of AI, ML, and LiDAR. The detailed literature review offers a deep understanding of the current landscape of UAVs, highlighting their revolutionary capabilities in diverse industries.
- The methodology section highlights crucial developments such as the implementation of efficient ML algorithms, hybrid UAV detection methods, and the employment of SLAM algorithms for object mapping.
- The conversation highlights the real-world applications of AI and ML algorithms in UAV technology, highlighting their crucial role in tasks such as object tracking, mapping, and voice control.
- By enhancing the versatility and effectiveness of UAVs, these innovative applications have the potential to greatly impact a range of tasks, from surveillance to disaster response. In particular, the discussion delves into the advancements in disaster scenarios, utilizing cutting-edge techniques such as web scraping and autonomous drones to showcase the tangible benefits of these technologies in addressing pressing challenges.
- The seamless integration of AI, ML, and LiDAR within UAV technology not only boosts operational abilities, but also offers groundbreaking solutions for enhanced environmental comprehension. As the field of research progresses, these advancements are sure to have a significant impact on the future of unmanned aerial systems in a variety of fields.

References

[1] Ahmed, F., Mohanta, J.C., Keshari, A. Et Al. Recent Advances In Unmanned Aerial Vehicles: A Review. Arab J Sci Eng 47, 7963–7984 (2022).

[2] Wang Z And Menenti M (2021) Challenges And Opportunities In Lidar Remote Sensing. Front. Remote Sens. 2:641723.

[3] Gourav Bathla, Kishor Bhadane, Rahul Kumar Singh, Rajneesh Kumar, Rajanikanth Aluvalu, Rajalakshmi Krishnamurthi, Adarsh Kumar, R. N Thakur, Shakila Basheer, "Autonomous Vehicles And Intelligent Automation: Applications, Challenges, And Opportunities", Mobile Information Systems, Vol. 2022, Article Id 7632892, 36 Pages, 2022.

[4] Pal, Osim & Shovon, Md & Ph. D., M. & Shin, Jungpil. (2023). A Comprehensive Review Of Ai-Enabled Unmanned Aerial Vehicle: Trends, Vision , And Challenges. 10.48550/Arxiv.2310.16360.

[5] Markiewicz, J.; Abratkiewicz, K.; Gromek, A.; Ostrowski, W.; Samczyński, P.; Gromek, D. Geometrical Matching Of Sar And Optical Images Utilizing Asift Features For Sar-Based Navigation Aided Systems. Sensors 2019, 19, 5500. Https://Doi.Org/10.3390/S19245500

[6] Welton, E.J., J. R. Campbell, J. D. Spinhirne, And V. S. Scott, 2001. Global Monitoring Of Clouds And Aerosols Using A Network Of Micro-Pulse Lidar Systems, Proc. Spie, 4153, 151-158.

[7] Nishizawa, Tomoaki & Sugimoto, Nobuo & Matsui, Ichiro & Shimizu, Atsushi & Higurashi, Akiko & Jin, Yoshitaka. (2015). Asian Dust And Aerosol Lidar Observation Network (Ad-Net): Strategy And Progress.
[8] Pappalardo, G., Amodeo, A., Apituley, A., Comeron, A., Freudenthaler, V., Linné, H., Ansmann, A., Bösenberg, J., D'amico, G., Mattis, I., Mona, L., Wandinger, U., Amiridis, V., Alados-Arboledas, L., Nicolae, D., And Wiegner, M.: Earlinet: Towards An Advanced Sustainable European Aerosol Lidar Network, Atmos. Meas. Tech., 7, 2389–2409, Https://Doi.Org/10.5194/Amt-7-2389-2014, 2014.
[9] De Mazière, M., Thompson, A. M., Kurylo, M. J., Wild, J. D., Bernhard, G., Blumenstock, T., Braathen, G. O., Hannigan, J. W., Lambert, J.-C., Leblanc, T., Mcgee, T. J., Nedoluha, G., Petropavlovskikh, I., Seckmeyer, G., Simon, P. C., Steinbrecht, W., And Strahan, S. E.: The Network For The Detection Of Atmospheric Composition Change (Ndacc): History, Status And Perspectives, Atmos. Chem. Phys., 18, 4935–4964, Https://Doi.Org/10.5194/Acp-18-4935-2018, 2018.
[10] Stewart, R.D., Auffret, M.D., Warr, A. Et Al. Assembly Of 913 Microbial Genomes From Metagenomic Sequencing Of The Cow Rumen. Nat Commun 9, 870 (2018).
[11] Wang Z And Menenti M (2021) Challenges And Opportunities In Lidar Remote Sensing. Front. Remote Sens. 2:641723. Doi: 10.3389/Frsen.2021.641723
[12] Eldien, Adly S. Tag. "Ai-Enabled Uav Communications: Challenges And Future Directions.
[13] Sarkar, Nurul I., And Sonia Gul. "Artificial Intelligence-Based Autonomous Uav Networks: A Survey." Drones 7.5 (2023): 322.
[14] Pal, Osim & Shovon, Md & Ph. D., M. & Shin, Jungpil. (2023). A Comprehensive Review Of Ai-Enabled Unmanned Aerial Vehicle: Trends, Vision , And Challenges. 10.48550/Arxiv.2310.16360.
[15] H. Kim, J. Ben-Othman, L. Mokdad, J. Son And C. Li, "Research Challenges And Security Threats To Ai-Driven 5g Virtual Emotion Applications Using Autonomous Vehicles, Drones, And Smart Devices," In Ieee Network, Vol. 34, No. 6, Pp. 288-294, November/December 2020, Doi: 10.1109/Mnet.011.2000245.