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AI Empowering Unmanned Aerial Vehicle Using Cloud Computing

Lamees R. Al-Jaburi[1*], Dr. Olusolade Aribake Fadare [2], Prof. Dr. Fadi Al-Turjman [3]

Master student at Department of Computer Engineering, Near East University, Nicosia, North Cyprus
[3]Artificial Intelligence Department Near East university, North Cyprus, Mersin-10, Turkey
[4] Artificial Intelligence Department Near East university, North Cyprus, Mersin-10, Turkey

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ABSTRACT

In the era of artificial intelligence and technology, unmanned aerial vehicles (UAVs) have become adaptable platforms with uses in many vital fields such as surveillance, reconnaissance, mapping, and others such as civilian and military environments. The UAVs are increasingly deployed across diverse sectors, necessitating robust path planning strategies for optimal mission execution. This report suggests integrating Artificial Intelligence (AI) technology, enabling Unmanned Aerial Vehicles (UAVs) to be integrated into the cloud infrastructure, thereby allowing ubiquitous access to them. The research introduces framework architecture by enabling efficient intelligent decision making for path-planning through complex networking. By leveraging AI for intelligent decision-making and cloud computing the UAVs can achieve enhanced autonomy, adaptability, and mission success rates and the challenges face for scalable and flexible computational resources.

Corresponding Author:

Lamees Ryadh Zyab
Master student at Department of Computer Engineering, Near East Unviersity, Nicosia, North Cyprus
Email: 20233784@std.neu.edu.tr

1. INTRODUCTION

The unmanned aerial vehicle (UAV), often referred to as drones, is an aircraft engineered or modified for operation without a human pilot aboard. The potential uses of UAVs in a wide range of fields are being expanded by the integration of cloud computing and artificial intelligence (AI) [1] AI and cloud technologies empower UAVs to execute missions with greater accuracy, efficiency, and autonomy. UAVs with artificial intelligence (AI) abilities can operate in challenging areas on their own, carry out inspections, keep an eye on interesting events, enhance methods for agriculture, and improve security and surveillance missions etc. UAVs can expand their capabilities and gain access to advanced tools and services thanks to cloud computing, which offers the infrastructure essential to storing and processing enormous quantities of data [2], Transportation, distribution, tracking, emergency assistance, and military service are only some of the industries that are changing as an outcome of this integration, and aerial vehicles today have more opportunities for innovation and effectiveness.

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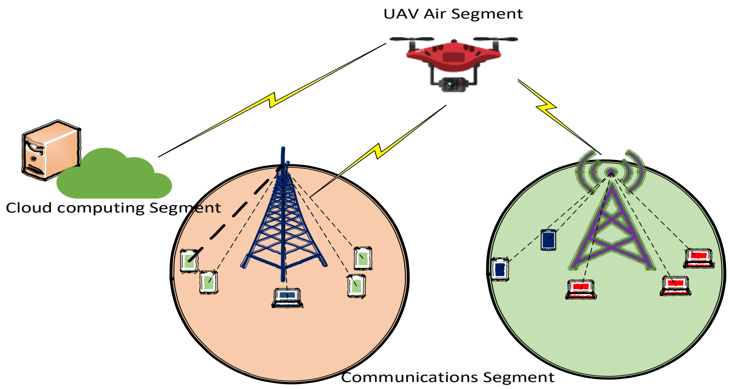

Figure 1: Overview of UAV system with cloud computing.

Before implementing actual infrastructure, it's crucial to evaluate the availability of UAV-based offloading systems to mitigate potential failures [3] The system segments can be illustrated in Figure 1 and explained below:

1) UAV Air Segment: This encompasses the collective count of unmanned aircraft, encompassing their individual components and potential payloads, typically comprising sensors[4].
2) Cloud Segment: Cloud computing, which offloads processing tasks to the cloud, has been a popular solution for this purpose, housing necessary equipment for aircraft piloting, mission monitoring, and flight planning.
3) Communications Segment: Comprises three distinct divisions-the Payload data link, Command and Control data link, and External Communications

2. LETURATURE REVIEW

In the realm of UAV communication systems, new challenges often arise. One of the primary concerns is the limited onboard energy available. Thus, it becomes crucial to maximize information transmission while simultaneously minimizing energy consumption. Additionally, minimizing energy usage in UAV systems extends beyond communication circuits and signal transmission; it also encompasses propulsion power consumption needed for movement and maintaining flight (Pandey.2019),. While trajectory optimization has been extensively researched, particularly for energy efficiency, it has not been specifically tailored for communication purposes. Many existing algorithms focus on energy-aware UAV path planning [5]; For example, some studies explore path optimization to minimize UAV energy consumption, but they do not consider communication performance. Similarly, other research investigates minimizing overall energy consumption while navigating towards a goal but overlooks communication aspects and may be affected by external factors like wind disturbances. This neglect of communication in energy optimization studies underscores the need for further research in this area.

In recent years, significant progress has been made in AI algorithms like reinforcement learning, artificial neural networks (ANN) [6] game theory, and deep learning. These algorithms have become essential in the realm of autonomous flight control and decision-making for Unmanned Aerial Vehicles (UAVs). In the context of UAVs, these AI techniques are transforming how UAVs navigate and plan their routes. Reinforcement learning allows UAVs to learn from their environment, enabling them to make informed decisions and improve their flight paths over time [7]. Artificial neural networks process complex sensor data swiftly, making decisions based on environmental information. Game theory provides strategic decision-making frameworks, enabling UAVs to anticipate and react to surrounding entities. Deep learning enables UAVs to recognize and respond to environmental factors accurately and efficiently by extracting patterns from vast data [8], The incorporation of these AI algorithms into UAV systems has revolutionized autonomous aerial operations. UAVs equipped with advanced AI capabilities can navigate complex environments, execute tasks precisely, and adapt to dynamic conditions in real-time. Consequently, they are transforming industries such as agriculture, infrastructure inspection, emergency response, and logistics by offering cost-effective and scalable solutions that were previously out of reach.

3. PATH-PLANNING CHALLENGES

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One of the challenges facing drone path planning is uncertain and dynamic environments because conditions change rapidly, making it difficult to predict, plan and determine paths accurately, so to solve this gap, drones can use advanced algorithms to analyze data perception and provide updated information about obstacles, terrain and other relevant factors. This is done by leveraging real-time sensor data such as LiDAR, cameras or radar to perceive the environment [9] Adaptive planning algorithms then integrate the information to dynamically update the planned paths in real-time, ensuring the drone can safely and safely navigate through uncertain, dynamic environments .

Secondly, the computational complexity of path planning methods can be a challenge, particularly when dealing with vast state spaces or complicated surroundings to control this challenge., By utilizing effective computational approaches, UAV path planning algorithms can be created to overcome computational complex. It is possible to effectively explore the search space and create paths by using graph-based search algorithms as A*, Dijkstra's algorithm or Rapidly Exploring Random Trees (RRT) [10].; Plans for paths in high-dimensional environments can be efficiently planned using sampling-based techniques such as Probabilistic Roadmaps (PRM) and Rapidly Exploring Random Trees (RRT). It is also possible to find optimal pathways while taking into account different limitations by using optimization-based techniques such as Genetic Algorithms (GA) or Mixed-Integer Linear Programming (MILP) [11].

Thirdly, Path planning frequently entails maximizing several kinds of aims that might conflict with one another. This gives an optimal trade-off ,The problem of optimal trade-offs can be addressed by using multi-objective optimization techniques [12] Multi-objective optimization algorithms can produce a collection of solutions that show trade-offs between competing objectives by specifying suitable objective functions and limitations. Based on their particular requirements and tastes, decision-makers can choose the best path of action from a Pareto front formed by these solutions.

In additionally Communication and Bandwidth Limitations [13] using cloud computing or ground station communication for routing can put UAVs in the face of limited bandwidth or unstable communication links Solution: UAVs can use decentralized path planning algorithms to lessen the effects of communication constraints. These algorithms minimize the UAVs' dependency on external communication by enabling it to make decisions relying on data collected from available sources and onboard sensors. Through the integration of onboard decision-making capabilities, unmanned aerial vehicles (UAVs) are able to independently modify their planned routes, even in situations where connectivity is sporadic.

4. Methodlogy and System Design

In UAVS, path planning is an essential factor for improving navigation and control (drones). It ensures an optimal and collision-free path between two locations from the starting point (source) to the destination (target) of autonomous drones while meeting the requirements of drone characteristics and service areas. Drone path planning needs to take some aspects into consideration including mission aims, sensor constraints, obstacle avoidance, drone dynamics, and real-time constraints. Furthermore, cutting-edge methods such as computer vision, machine learning, and sensor fusion can be applied to improve the accuracy and effectiveness of UAV path planning algorithms.

a. UAV Sensor Technology

UAVs typically gather data through sensors onboard their hardware. This data can be processed onboard or transmitted to a ground-based station for further analysis. When it comes to UAV path planning and obstacle avoidance, advanced algorithms and software are employed to analyze sensor data, extract relevant information, and make informed decisions. It's important to note that the choice of sensors and sensing technologies for a UAV is influenced by factors such as its intended use, the surrounding environment, payload restrictions, and budget constraints[14],. UAV operators and engineers carefully consider mission requirements, as well as the desired level of functionality and precision of sensing, when selecting the appropriate sensors. This ensures that the UAV is equipped with the necessary tools to effectively carry out its tasks while operating within the constraints of its operational environment and resource limitations.

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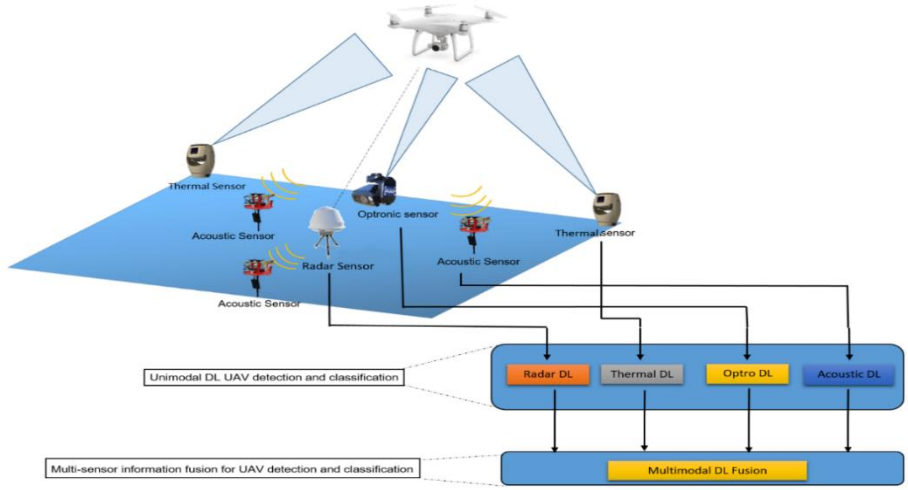

Figure 2: UAV Sensor Technology

The common sensor onboard of UAV are shown in Figure 2 and explained below:

1. Camera, onboard imaging systems, gather visual information about the UAV's surroundings. They capture images or videos that serve multiple purposes, including object detection, terrain mapping, and navigation. Subsequently, computer vision algorithms are utilized to analyze this visual data, extracting important features and identifying obstacles within the environment [15].
2. LiDAR (Light Detection and Ranging) sensors utilize laser pulses for distance measurement, generating a 3D depiction of the UAV's surroundings. Through LiDAR, a point cloud is formed, offering detailed insights into object positions, terrain elevation, and potential obstacles. This information is crucial for obstacle identification, terrain mapping, and precise localization.
3. Ultrasonic sensors emit high-frequency sound waves and assess the time it takes for these waves to return after encountering an object. They are frequently employed for detecting obstacles at close range and maintaining altitude. These sensors offer distance calculations and aid UAVs in steering clear of potential collisions with nearby objects.
4. GPS (Global Positioning System) receivers allow UAVs to ascertain their exact position and speed through satellite signals. This data aids in navigation, guiding waypoints, and geolocation. However, GPS signals may encounter challenges, such as signal disruption or reduced precision in environments like urban areas or dense foliage [16].
5. Inertial Measurement Units IMUs, composed of accelerometers, gyroscopes, and magnetometers, measure the UAV's acceleration, rotation rate, and magnetic field orientation. They provide vital data for UAV stabilization and control, enabling estimation of the UAV's position and velocity through continuous measurement integration.

b. UAV Cloud-Computing

In the context of UAV data processing in cloud computing, several aspects like data collection, processing, transmission, and mining are involved. However, for simplicity, this article abstracts these complexities into a simple model relevant to UAV service scenarios. In these scenarios, devices are typically distributed widely and exhibit flexible movement patterns. Traditional ground-based stations encounter significant challenges in providing adequate service coverage to these distributed devices [17].

With the use of cloud computing, unmanned aerial vehicles (UAVs) can now carry out complex missions, access huge quantities of storage, and take advantage of real-time data processing. The combination of cloud computing with UAV systems will open up new opportunities and drive innovation in a range of sectors and applications as cloud technologies continue to develop.

Cloud computing UAVs make use of cloud resources to improve performance, such as:

1. offloading computational tasks
2. Adaptable storage capacity
3. Processing data in real time

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4. cooperative endeavors
5. Mission control using remote means
6. Updates for firmware and software
7. Machine learning and data analytics
8. efficiency of cost.

c. Cloud Computing of UAV path-planning

The cloud computing process for planning the path of drones consists of a set of steps, which first begins with collecting, managing, and preparing data and information. Relevant data, such as maps of environmental terrain and weather conditions, are collected and prepared for analysis, and then they are stored in the cloud storage, which works on Store prepared data securely in the cloud for easy access and scalability during the planning process. Then the cloud services run a specialized algorithm called the path planning algorithm, which computing the best paths and suitable routes for drones based on the available data and for To speed up calculations, parallel processing technology is used[18],. Strict security measures must also be provided and implemented to maintain the integrity of information data and ensure compliance with regulatory standards. The path planning system must also be seamlessly integrated with other drone control and monitoring tools through application programming interface (API) integration, and because the cloud infrastructure is designed with the ability to scale up or down as needed. Through effective management of resources to improve its performance and through continuous improvements and developments driven by user feedback and technological advances, the system improves to become more efficient and effective.

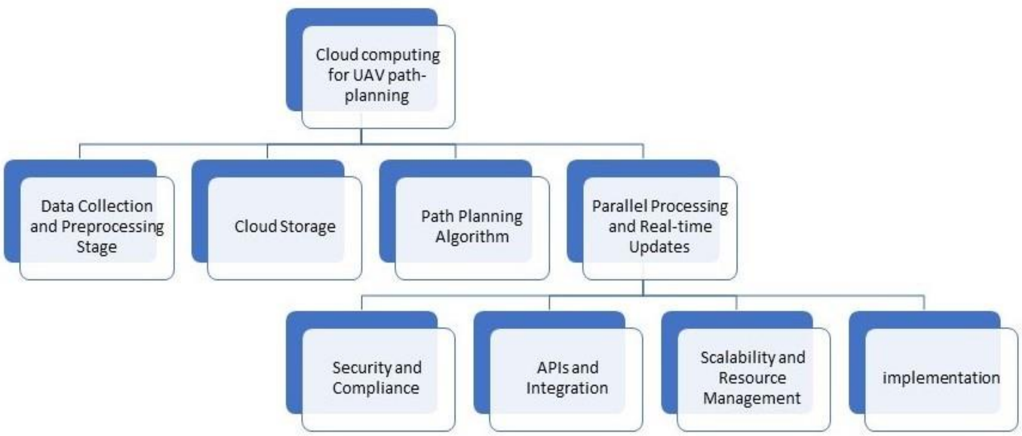

Figure 3: Cloud computing for UAV path planning

d. Framework Design For Safe UAV Operation

The operational environment framework design for the drone, as illustrated in Figure 4, provides a systematic process for ensuring safe and efficient flight operations. Beginning with the loading of the flight plan, which is meticulously designed to accommodate the specific needs of crops, the drone sets its course for the designated fields. However, before takeoff, the drone prioritizes gathering crucial weather data from the nearest weather station. This data includes wind speed, a critical factor in determining flight safety. If the wind speed surpasses a predetermined threshold, indicating potentially hazardous conditions, the drone halts its operations and patiently awaits the next opportune moment for flight. In parallel, the algorithm continuously monitors rainfall levels. Excessive rainfall can not only impede the drone's manoeuvrability but also pose risks to crop health. Should the rainfall exceed a predefined threshold, the drone intelligently terminates its flight, avoiding potential damage to both itself and the crops it aims to serve [19]

Assuming all weather conditions are within acceptable parameters, the drone proceeds to evaluate its energy reserves. A comprehensive assessment ensures that the drone possesses adequate energy levels to complete its designated tasks. If energy levels fall below the required threshold, the drone proactively terminates its flight, preventing the possibility of an involuntary shutdown mid-flight. Furthermore, the algorithm incorporates a proactive approach to connectivity. The drone actively searches for ground base station connection requests, prioritizing seamless communication for data transmission. Upon detection of a ground base station requiring connection, the drone swiftly establishes a link, facilitating the exchange of essential data. Once all data transmission is complete, the drone efficiently sends a disconnect message, signaling the end of the connection. To optimize operational efficiency and conserve resources, the algorithm directs the drone to enter sleep mode for a predefined period after completing its tasks. This strategic decision minimizes potential interference from other ground base stations within the coverage range, ensuring uninterrupted operations in subsequent flights.

In essence, the operational environment algorithm for the drone embodies a sophisticated blend of proactive decision-making, real-time data analysis, and strategic resource management. By systematically navigating through various operational factors, the algorithm enables the drone to execute its missions with precision, reliability, and safety at the forefront of its operations.

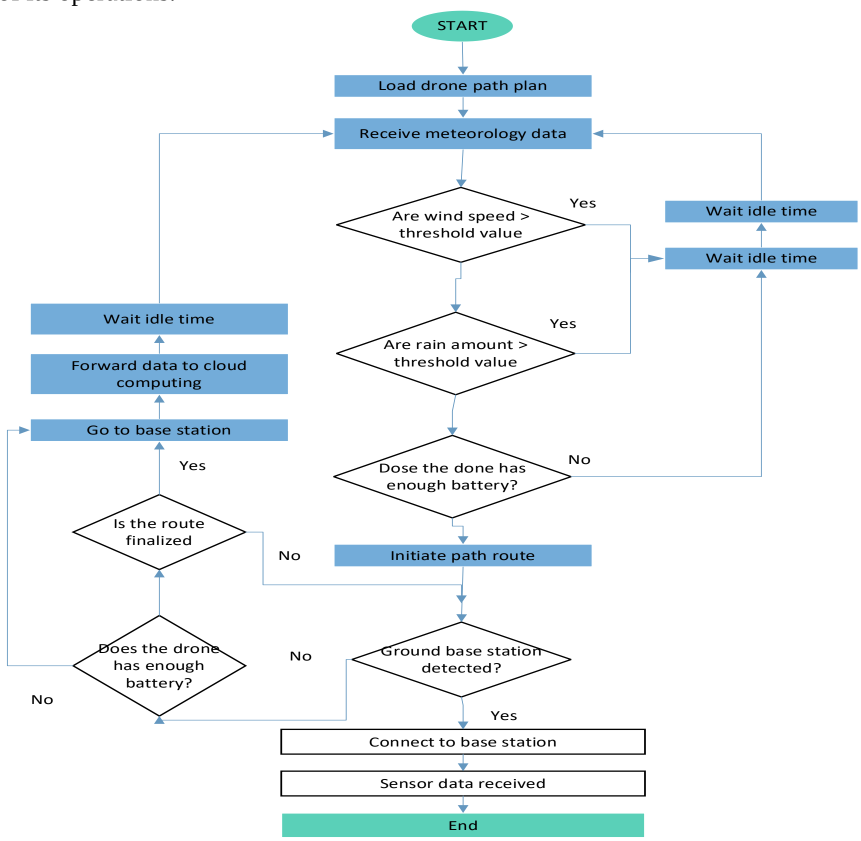

Figure 4:Framework Design of Cloud-assisted UAV Path planning

e. Cloud-assisted UAV applications

Applications for cloud-assisted unmanned aerial vehicles (UAVs) describe how cloud computing technologies are used to improve the efficacy and capabilities of UAVs in a variety of scenarios. Here's a further breakdown of a few of these uses:

1) Cloudassisted Unmanned Aerial Vehicles (UAVs) are utilized for surveillance and monitoring purposes from the air, including border control, law enforcement, and critical infrastructure monitoring. High-resolution imagery is taken by UAVs and sent to the cloud for instantaneous processing [20], Cloud-based algorithms can find and follow objects of interest, giving operators and security staff important information.
2) Cloud computing makes it possible for unmanned aerial vehicles (UAVs) to gather and analyze data about crop health, soil properties, and weather trends in precision agriculture. Agricultural fields are photographed by multispectral or thermal UAVs fitted with sensors, and the images are uploaded to the cloud for processing. In order to help farmers make data-driven decisions that maximize yields, cloud-based algorithms evaluate crop health, pinpoint nutrient deficits, find pest infestations, and optimize watering techniques.
3) Cloudassisted unmanned aerial vehicles (UAVs) are essential for collecting and analyzing key data in disaster response and management situation.UAVs with cameras and sensors evaluate the harm caused by natural disasters and provide data for in-the-moment analysis to the cloud.

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Emergency response teams receive situational awareness from cloud-based analytics, which also help with damage assessment and search and rescue operations [21]

4) By optimizing logistics, route planning, and fleet management, cloud computing improves UAV delivery services. Cloud-based algorithms optimize delivery routes in real-time by taking into account factors including item weight, delivery locations, traffic conditions, and predictions of the weather. By controlling inventories, directing several UAVs, and giving clients real-time data, the cloud also makes order fulfillment more efficient.
5) Monitoring the environment: By gathering and evaluating information on the state of the air, water, and wildlife habitats, cloud-assisted unmanned aerial vehicles (UAVs) help in environmental monitoring initiatives. Sensitive environmental factors are recorded by UAVs fitted with dedicated sensors, which then send the information to the cloud for processing. To assist in environmental preservation and decision-making, cloud-based algorithms analyze the data, spot trends, and produce insights.
6) Monitoring and traffic control: Realtime traffic data, such as traffic volume, collision rates, and road conditions, are captured by cloud-assisted unmanned aerial vehicles (UAVs). The cloud receives this data so it can be processed and examined there. In order to improve overall traffic efficiency and increase public safety, cloud-based algorithms optimize traffic flow, give real-time traffic updates, and help detect incidents or infractions.
7) Media and entertainment: To capture aerial footage and broadcast live events, cloudassisted unmanned aerial vehicles (UAVs) are being employed more and more in this sector. Real-time editing, processing, and distribution are made possible by UAVs fitted with high-quality cameras, which send the recorded video to the cloud. Media workers may create content, broadcast live, and create immersive experiences with the use of cloud-based technologies.

f. Making Decision and analysis

In situations where drones operate autonomously without human intervention, the decision-making process of Unmanned Aerial Vehicles (UAVs) becomes crucial. UAVs rely on sophisticated models and algorithms to make informed decisions based on environmental data they gather. Various operations such as search and rescue, emergency preparedness, monitoring, and warfare scenarios heavily rely on this autonomous decision-making capability [22].

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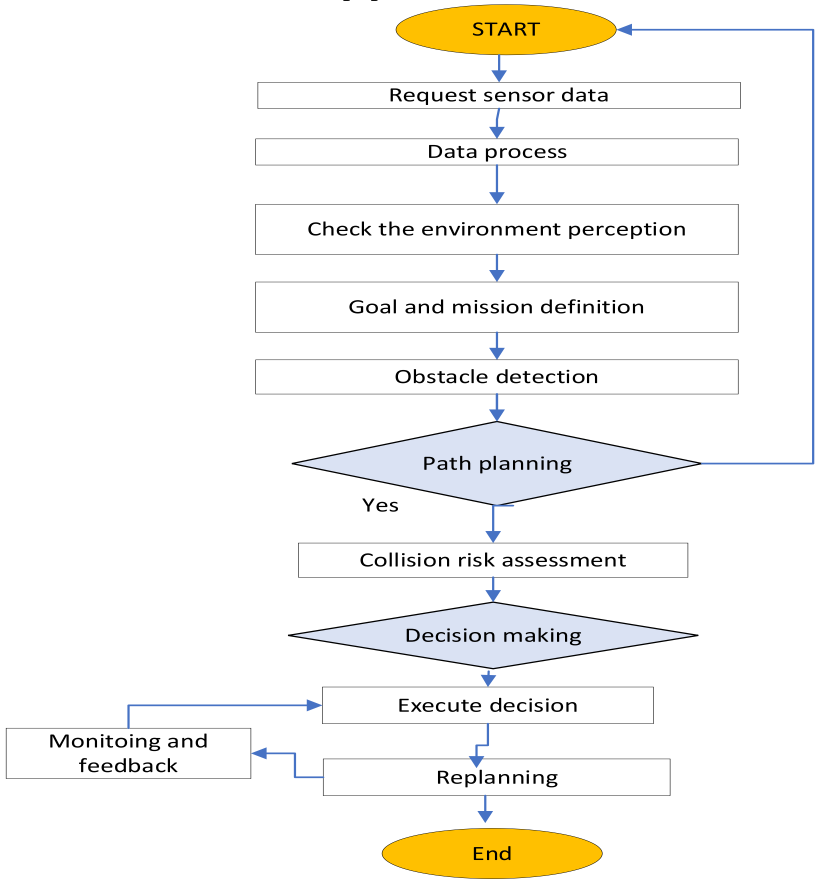

Figure 5: Flowchart design for decision making for path

Operators must consider challenges like insufficient environmental data, unpredictability in target detection, and the need for autonomous navigation in unstructured areas. To address these challenges, scholars are exploring techniques such as hierarchical learning, reinforcement learning, dynamic game theory, and deep reinforcement learning to enhance UAV decision-making capabilities. In determining the most suitable course of action, algorithms analyze both mission objectives and sensor data. Tasks include selecting optimal waypoints, avoiding obstacles [23] and dynamically adjusting speed and elevation to optimize performance and align with mission goals. This intricate decision-making process enables UAVs to operate effectively in diverse and dynamic environments. Figure 4. flowchart gives a visual depiction of the steps involved in making decisions for UAVs: gathering sensor data, processing it, observing the surroundings, establishing objectives and a mission, planning the route, spotting impediments, estimating the likelihood of a collision, making decisions, carrying them out, observing feedback, and modifying or rearranging as necessary.

The decision-making process as follow:

1 Data-collection: Unmanned Aerial Vehicles (UAVs) employ multiple sensors, including cameras, LiDAR, GPS, and IMUs, for gathering information or data about the environment, challenges, and locations.
2 Mission planning: Describe mission goals and objectives, including accessing the target, observing, or mapping the area.
3 Analysing Data: The collected data is analyzed by algorithms to extract important details such as obstacle' places, the UAV's directions, and environmental conditions.
4 Decision criteria: Determine decision-making criteria based on data analysis and mission objectives. Using these criteria, the drone can decide what steps to take to achieve its goals.
5 Route planning: Algorithms determine a path or paths that drones should follow based on decision criteria. This route includes essential variables such as waypoints, barriers, terrain, and obstacle avoidance.

Unmanned aerial vehicles could make decisions instantly through the application of remarkable algorithms and models to assess the data from their surroundings, sensors, and mission objectives. Sensors work together with flight characteristics, mission objectives, and obstacle detection, among other things, in various cases where the factors are examined when making the decision .Through the application of the onboard computing system to analyze this data and make conclusions, UAVs often navigate complex environments and behaving appropriately in challenging situations that keep varying without human intervention. Decision-makers must examine an array of factors relevant to the action, forecast potential outcomes, and make a decision to achieve mission objectives and reduce flight time.

5. CONCLUSION

This paper examines how to integrate and leverage artificial intelligence (AI) and cloud computing with unmanned aerial vehicle (UAV) operations with a particular focus on path planning and decision-making procedures, Because drones are now adaptable platforms, they are used in a variety of fields, such as mapping, reconnaissance, and surveillance [24] In order to maximize mission performance, effective path planning techniques are essential.

This report makes recommendations for integrating AI algorithms and cloud infrastructure to enable drones to take advantage of unlimited access and scalable processing resources. autonomy Enhancing, flexibility and missions success rates of UAVs are provided by this combination. Drones can plan across complex efficiently surrounding environments by depending on artificial intelligence to make intelligent decisions.

For UAV operations, the combination of AI algorithms and cloud computing offers several advantages. By utilizing cloud-based resources, it enhances flexibility, increases mission success rates through intelligent decision-making, and augments autonomy by allowing UAVs to adjust to changing situations [25].

The report describes an operating environment framework for UAV or drones that ensures safe and effective flying operations. The framework's first step in determining flight safety is to evaluate the weather, particularly the wind and rainfall. To ensure that the operation runs smoothly, the drone also monitors its energy levels. In addition to enabling smooth data transmission between ground base stations, the algorithm sleep mode enters post-mission to provide strategic resource management. Overall, this methodical strategy [26] combines proactive decision-making with real-time data analysis to improve the precision, dependability, and safety of drone operations.

In general, the research emphasizes how important it is to integrate cloud computing, AI algorithms, and intelligent decision-making into UAV operations. Mission success rates are raised, autonomy and adaptability are improved, and effective path planning is made possible by this collaboration. UAVs can further reinforce their status as essential instruments in the age of artificial intelligence and technology by utilizing the power of AI and cloud computing to unleash new possibilities and improvements in a variety of areas.

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