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Systematic Review of Unmanned Aerial Vehicles Control: Challenges, Solutions, and Meta-Heuristic Optimization

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ABSTRACT

Unmanned Aerial Vehicles (UAVs) are powerful tools with vast potential, yet they face significant challenges. One of the primary issues is flight endurance, limited by current battery technology. Researchers are exploring alternative power sources, including hybrid systems and internal combustion engines, and considering docking stations for battery exchange or recharging. Beyond endurance, UAVs must address safety, efficient path planning, payload capacity balancing, and flight autonomy. The complexity increases when considering swarming behaviour, collision avoidance, and communication protocols. Despite these challenges, research continues to unlock UAVs' potential, with path planning optimization significantly advanced by meta-heuristic algorithms like the Cuckoo Optimization Algorithm (COA). Whereas, meta-heuristic algorithms can be defined as system-level strategies that are used to seek suboptimal solutions to optimization problems. It uses heuristic approaches together with the exploration/exploitation scheme in order to effectively employ within large solution spaces. However, dynamic environments still present difficulties. UAVs have evolved beyond recreational use, becoming essential in industries like agriculture, delivery services, surveillance, and disaster relief. By resolving issues related to autonomy, battery longevity, and security, the benefits of UAV technology can be fully optimized. This systematic review emphasizes the importance of continuous innovation in UAV research to overcome these challenges.

1. Introduction

Drones are changing traditional fields including transportation, farming, emergency response, and many other fields. These systems are capable of executing operations which are either too sensitive, timely, or laborious for people to accomplish. More recently Unmanned aerial vehicles (UAVs) have been used in various scenarios ranging from aerial delivery of life essentials in disaster areas to aerial surveying in precision farming by use of Quad-Copter to survey crops as well as the soil. Such custom labels, they are indispensable; especially in cases where you need to come up with quick solutions for specific emergencies. Nevertheless, a huge potential remains unexplored concerning UAV's working characteristics and best practices to implement its various uses to their full potential. In the past 1.5 decades of remarkable deployment of UAVs, technological breakthroughs in machine learning (ML), artificial intelligence (AI), data digitization and the building of advanced computing infrastructures have been made. UAVs can perform tasks using these technologies that would previously have been considered to require human expertise such as detailed aerial inspections, precise delivery and real-time environmental monitoring. For instance, AI-enabled UAVs with sensors can be used to assess crop health, predict crop output, and assist utilization of resources like water or fertilizer in agriculture. A lot of work has been done to build systems that can properly predict and optimize UAV performance, but such predictions are quite impractical given the large amounts of very demanding tasks to do. This brings us to one important thing: These positions the problem as one of how to improve the autonomy and decision-making ability of UAVs operating in dynamic and unpredictable systems, such as disaster zones or congested airspace. In addition, the safety and security of UAV operations has become an increasingly pressing concern as UAV operations begin to see more implementation as a component of the civilian and commercial airspace. UAV technology has a bright future, tailored specifically to incorporate AI systems that can predict, prevent and manage the risks that exist. Under the influence of predictive analytics and real-time data processing, UAVs can do even better in their respective sectors. By filling in current gaps, these advancements will allow UAVs to operate with more precision, reliability and safety, and broaden the use of UAVs in many additional sectors. Fig. 1 and Fig. 2 illustrate control structures, respectively [1], [2].

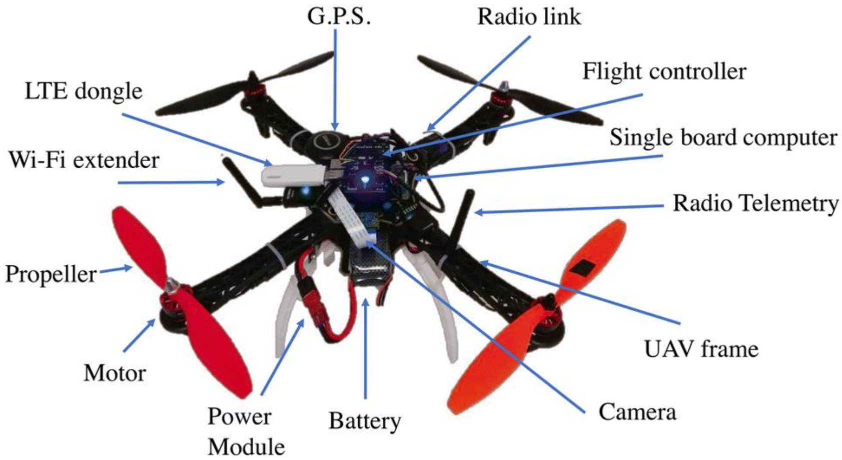

Fig. 1. UAV components [1]

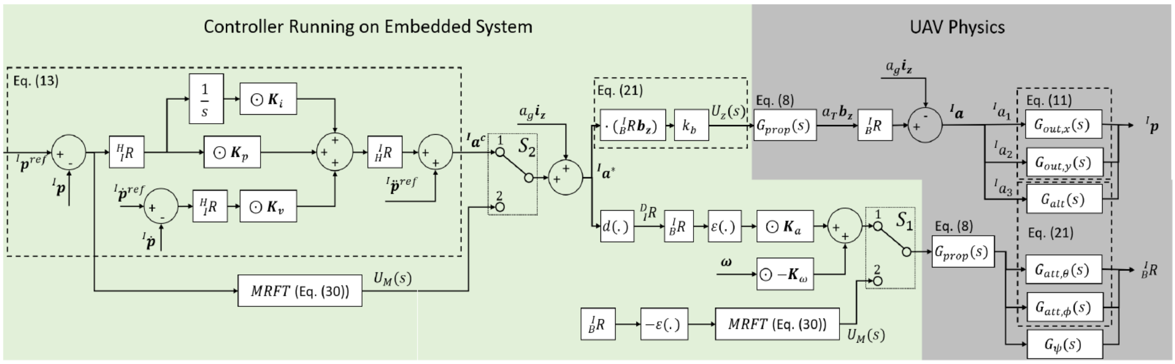

Fig. 2. UAV control running design [2]

To set the workflow for this particular study, which focuses on the domain of UAVs, the current literature on data mining and machine learning approaches was surveyed in order to get acquainted with prior approaches to and developments in the field with regards to the Prediction, Regression, and Classification. The review also presents the UAV control-related studies utilizing ML applications, as categorises by the application types, the accuracy, evaluation techniques, and application of machine learning and data mining algorithms. The sources are cited and annotated on the datasets utilized in the current study and in the literature. By considering the process and result of the approaches, the study aims at exploring the reasons, issues, and shortcomings, and Chinese solutions to them in order to provide suggestions on increasing effectiveness. Further statistical data are provided in more specific tables that contain worked examples related to the topic of Classification and main features of UAVs. The paper is organized as follows: the last section includes a conclusion and some general remarks, while the second section talks about the research method used in the sampled studies [3], [4].

2. Methods

In this study, the format for the literature review was in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [5], [6]. The four digital databases that we selected are ScienceDirect (SD), IEEE Xplore, Web of Science (WoS), and Scopus. Users of SD have access to a highly respected journal of science and technology. Current research papers on computer science, electronic engineering, and the application of engineering and computer technology to unmanned aerial vehicles (UAVs) can be found in IEEE Explore [7], [8]. Regarding the social sciences, engineering, science, humanities, arts, and multidisciplinary studies, WoS is an incredibly trustworthy source. A trustworthy resource for a variety of research topics, including science, technology, engineering, and unmanned aerial vehicles, is Scopus. All scholarly facets of UAVs are covered by the four databases. This literature review's findings can advance UAV technology by offering in-depth knowledge in this area, existing UAV systems, and recommended solutions for developing reliable UAV systems as shown in Fig. 3.

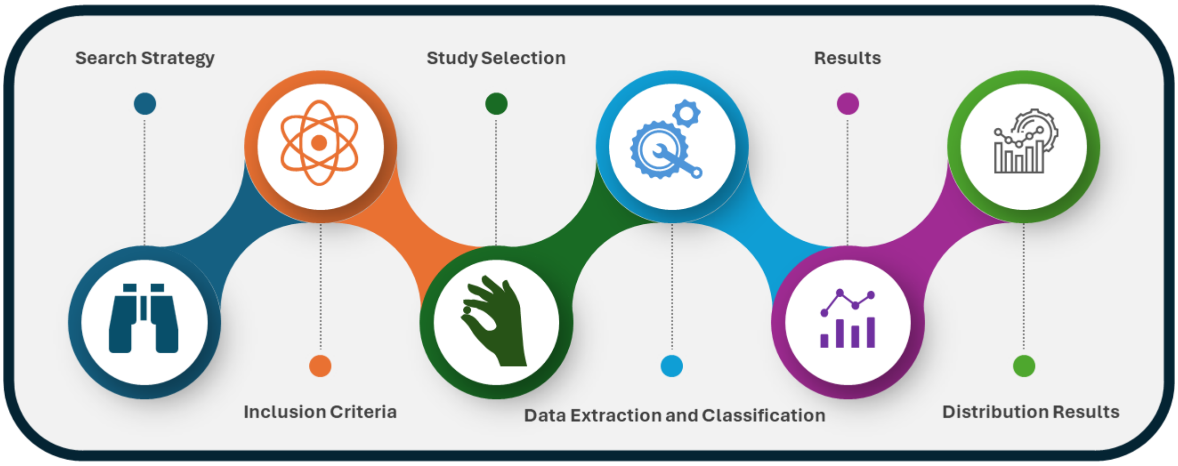

Fig. 3. Search strategy, selection, and results method

2.1. Search Strategy

A thorough literature search for English language citations published between 2014 and up to 06-March 2024 was carried out in the four databases. These indices were chosen because, given the identified novel UAV's need for more attention, they adequately covered studies relevant to our investigation. This study implemented three Boolean search strategies using different keywords associated with the ubiquitous term "unmanned aerial vehicle," such as "unmanned aerial vehicles" OR "UAV". These query strategies helped us narrow down the array of AI and ML systems we were looking for as well as UAV application studies.

2.2. Inclusion Criteria

- The article is a conference paper or journal published in English.

- Various applications, systems, algorithms, methods, and techniques related to machine learning and artificial intelligence are the focus.
- All that is being developed is the adaptive UAV's control, trajectory, and classification. Fig. 4 shows the pie chart for all four databases (ScienceDirect (SD), IEEE Xplore, Web of Science (WoS), and Scopus). Overview of the boolean search query sequences and outcomes in Table 1.

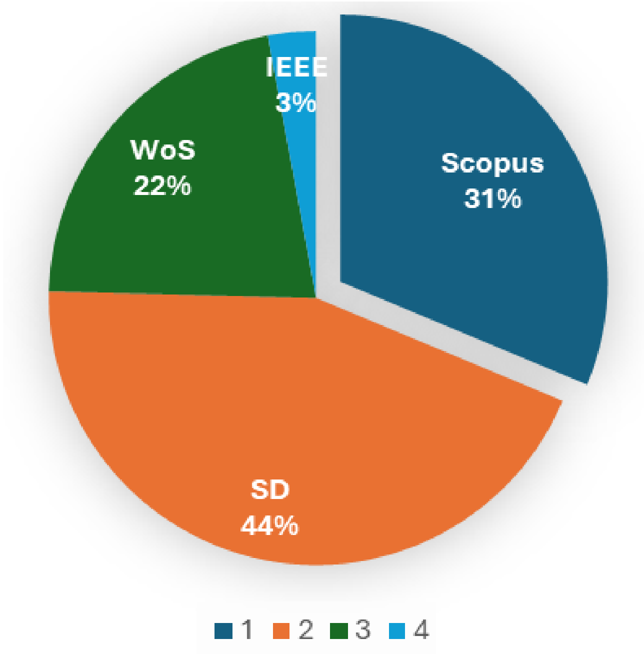

Fig. 4. Pie chart for all four databases

Table 1. Provides an overview of the boolean search query sequences and outcomes used in this work

Seq.	Query Details Terms	Result of Databases	Final Results
1st query	('unmanned aerial vehicle' OR 'unmanned aerial vehicles OR 'UAV') AND ('unmanned aerial vehicle system' OR 'unmanned aerial vehicles system' OR 'Autonomous unmanned aerial vehicles system' OR 'unmanned aerial vehicle navigation' OR 'Unmanned aerial vehicle flight' OR 'drone(s)')	SD = 325 IEEE = 13 WOS = 192 Scopus = 249	779−12 (duplicates) = 767 Article(s)
2nd query	('unmanned aerial vehicle' OR 'unmanned aerial vehicles OR 'UAV') AND ('unmanned aerial vehicle system' OR 'machine learning' OR 'artificial intelligence' OR 'optimization')	SD = 201 IEEE = 10 WOS = 90 Scopus = 136	437−9 (duplicates) = 428 Article(s)
3rd query	('unmanned aerial vehicle' OR 'unmanned aerial vehicles') AND ('machine learning' OR 'artificial intelligence') AND ('controller' OR 'embedded controller')	SD = 125 IEEE = 20 WOS = 38 Scopus = 78	261−3 (duplicates) = 258 Article(s)
Final results for all queries			**1453 Articles**

2.3. Study Selection

In order to determine whether a given article meets our inclusion and exclusion criteria, duplicate articles were removed and non-duplicate articles were screened based on their titles and abstracts. A thorough reading process was applied to the pertinent articles in order to gather and extract research data and create the review article. To guarantee the creation of a highly dependable and helpful research paper, a senior author (corresponding author) oversaw and supervised the entire research process in each research article.

2.4. Data Extraction and Classification

The aim of this comprehensive analysis is to evaluate AI detection efficacy, navigation, and classification of UAVs through data extraction and classification of the chosen studies [9]. This was done in light of the multidisciplinary nature of the topic, particularly ML techniques [10]. The nationalities of the authors, the publication date, the number of articles published annually, and the number of articles per database were among the data elements that were taken from scholarly literature. This study addressed UAVs and examined their global usage growth scale when it comes to artificial intelligence, a range of data mining and machine learning techniques, such as classification, regression, and prediction, in order to provide a thorough understanding of UAVs [11]. This study retrieved the key feature names, assessment techniques, and accuracy status for every study found in the literature [12]. In order to address the grave public concern regarding UAVs, The reviewed papers provided a brief motivation, challenges, limitations, and recommendation. Fig. 5 depicts the techniques that were used in UAV as Word-Arts.

Fig. 5. UAV Techniques as word-arts

2.5. Results

Fig. 6 displays the outcomes of the search queries used for this investigation. During the data collection process, We used three search queries to search all databases and the search engines that are connected to them. From all four databases, 1453 articles were included in the first result. There were 1429 unique articles after 24 duplicates were found in all databases. The articles were then screened using the title and abstract as a guide, and inclusion and exclusion criteria were then applied. There were 185 articles as a result. After carefully going over each article, only ten of them satisfied the inclusion and exclusion criteria in the last phase. We analyzed each study with the help of two similar sequences found in the systematic review search query because we knew the purpose of these studies. The article's identification of the UAV should come first, followed by the UAV's use.

2.6. Distribution Results

Fig. 7 provides a Sankey diagram (three fields plot) of these algorithms and methods refers to study type, journal name and technique type. The Nonlinear Model Predictive Control (NMPC) was the most commonly used, appearing four times and the remaining algorithms and methods were each used once, both urban and networks were applied once. Additionally, systems were records around 14 includes 7 for Journal of Computer and System Sciences and 2 for Ocean Engineering and the remaining journals were each used once.

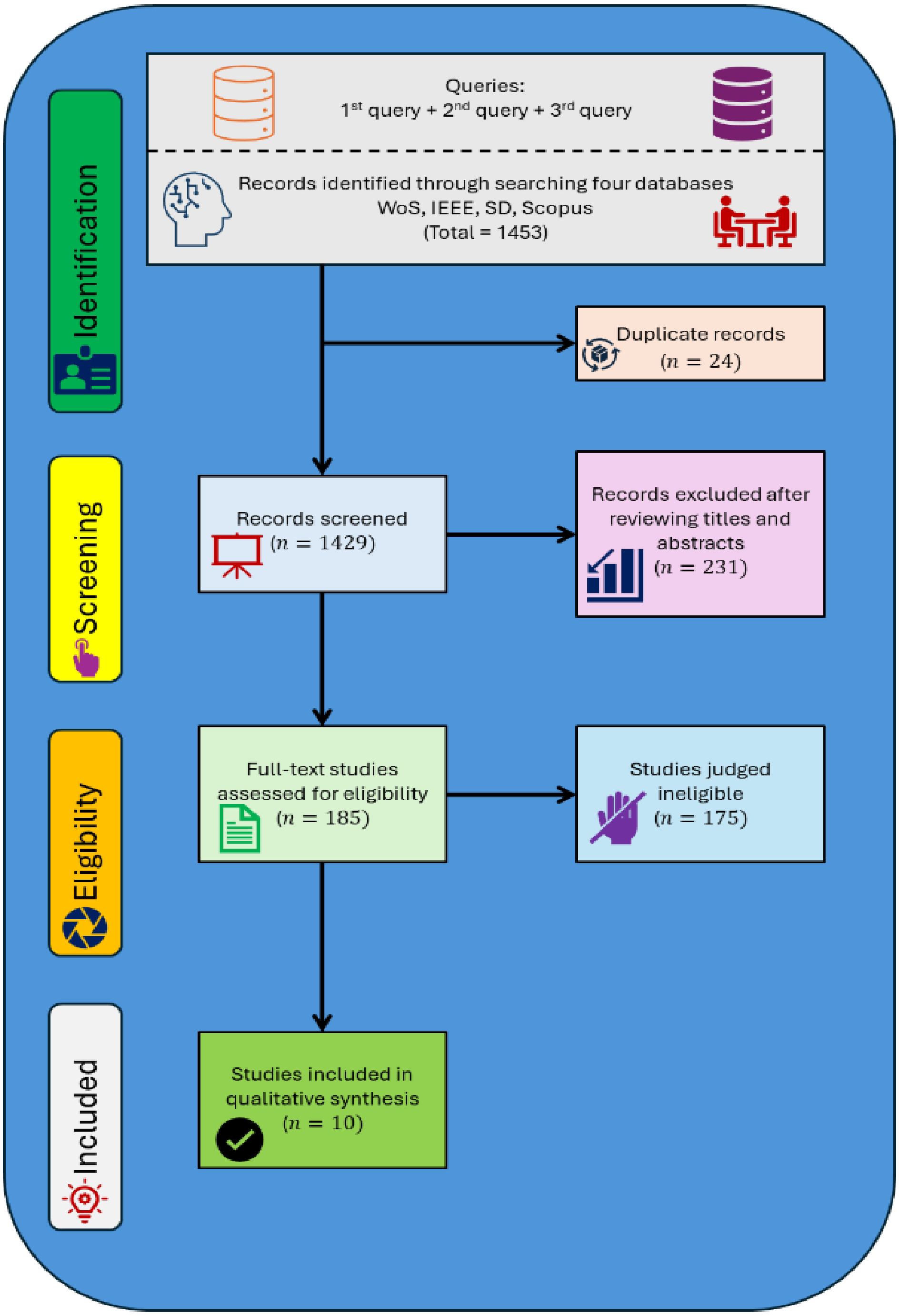

Fig. 6. Diagram outlining the process for finding, evaluating, and incorporating pertinent studies

Fig. 8 shows how many papers were included in the review of academic literature after the year of publication. The distribution of research publications between 2014 and up to 06-March 2024 is displayed below. In 2023, three papers were released. In 2019, 2022, and 2024, two papers were published in each year. In 2021, only one paper was released. The other years saw the publication of no papers. The state-of-the-art UAV with ML and optimization algorithm(s) is shown in Table 2. The descriptions of the UAV datasets and their sources are shown in Table 3.

3. Discussion

Fig. 9 illustrates many of the key points that are discussed in order to determine the research gaps, as indicated by the analysis.

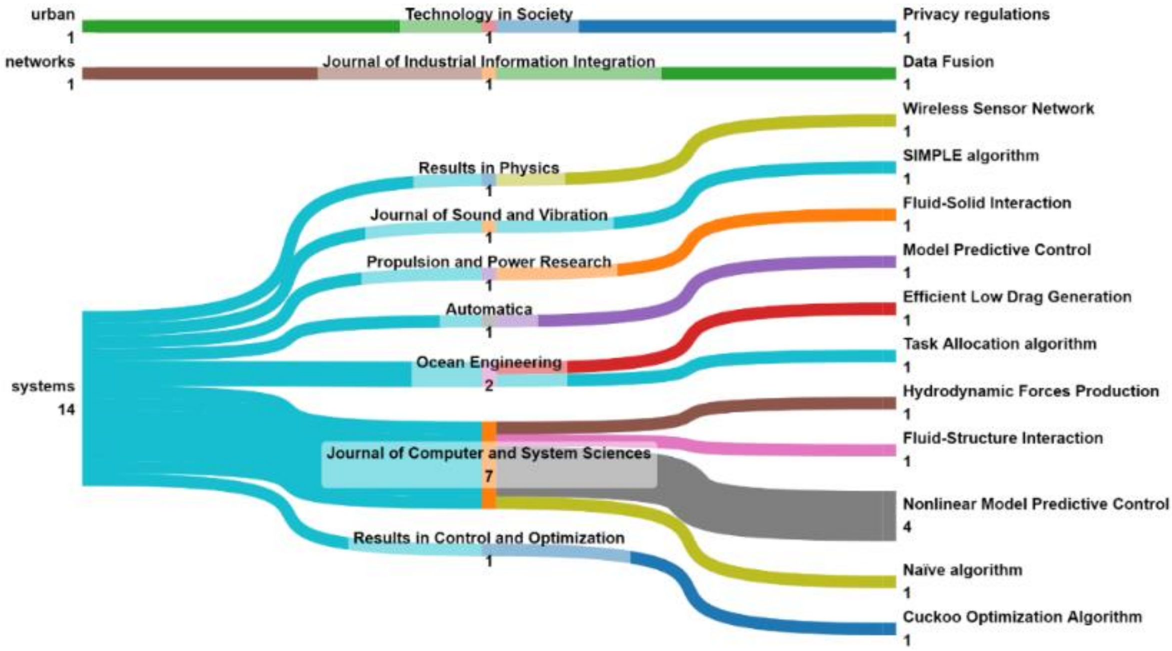

Fig. 7. Sankey Diagram for methods and algorithms against journals and application type

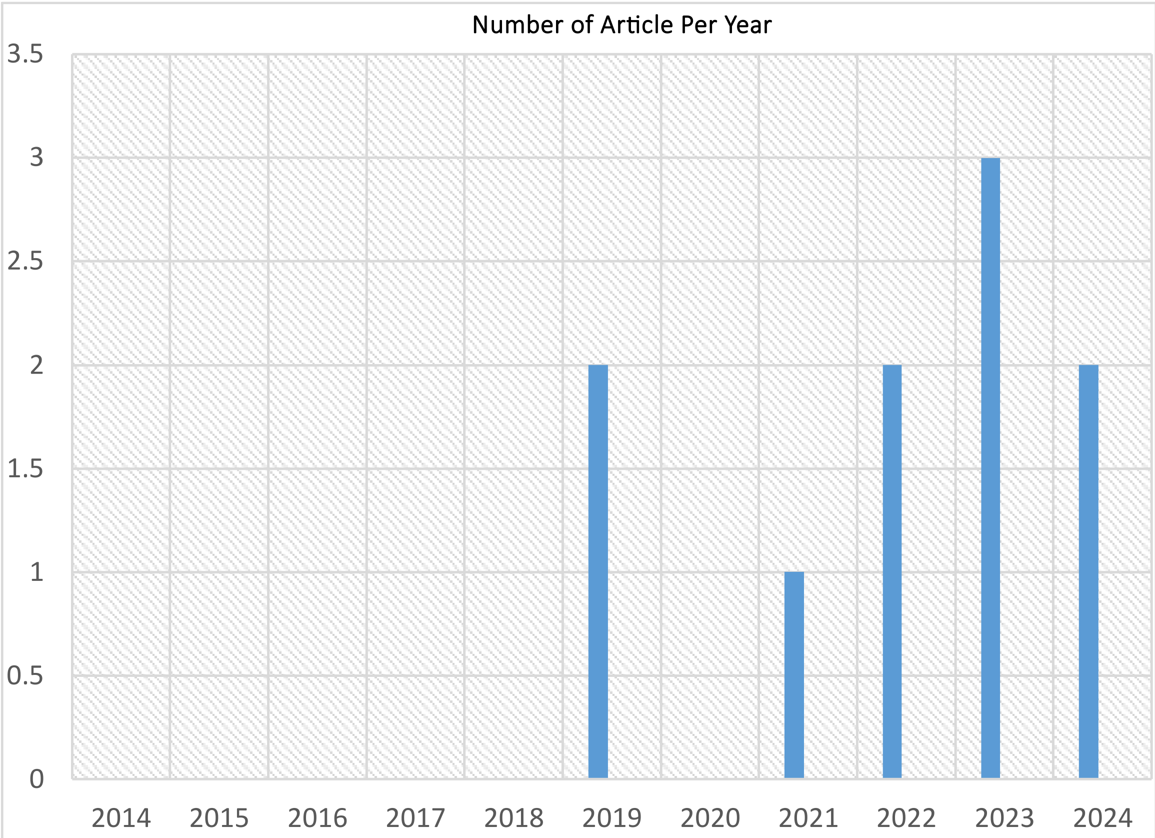

Fig. 8. Synopsis of the techniques and algorithms applied in the literature review

In [13], one wireless sensor network and physical simulation was applied to the UAV dataset to identify the best precise route control system for UAVs. The results showed that the wireless sensor network and physical simulation are the best models to enhance UAV flight path accuracy and stability. In [14], one SIMPLE algorithm is applied to the UAV rotor system dataset, and the SIMPLE algorithm shows higher prediction proficiency than experimental measurements.

Table 2. State-of-the-art UAV with ML and optimization algorithm(s)

Ref.	System Nature	Machine Learning and Optimization algorithm(s)	Evaluations	Accuracy
[13]	Precise route control of unmanned aerial vehicles (UAVs).	Wireless Sensor Networks.	Stability and accuracy in flight tests.	-
[14]	Improve the route control system for unmanned aerial vehicles.	SIMPLE algorithm.	Accuracy for route planning and execution.	-
[15]	Analyze and compare safety and privacy regulations.	Privacy regulations.	-	-
[16]	Identify aeroelastic properties of the propulsion system used in ion propulsion UAVs	Fluid-Solid Interaction.	Assessing and analyzing the behavior and performance of the propulsion system used in ion propulsion UAVs	Elastic state=12.2% Drag coefficient=25.8 %
[17]	Improving the technology and public perception of swarming drones.	Swarm Intelligence algorithms	-	-
[18]	The use of robust optimization methods for the design, components, performance, and material optimization of the vehicle.	Efficient Low Drag Generation, Model Predictive Control, Hydrodynamic Forces Production, Fluid-Structure Interaction	theoretical calculations, computational simulations, and experimental testing	Design ratio: 75% — 100%
[19]	Combine the capabilities of rotary-wing and fixed-wing vehicles for hybrid UAVs.	Model Predictive Control, Hydrodynamic Forces Production, Fluid-Structure Interaction, and Nonlinear Model Predictive Control	real-world flight experiments	($\boldsymbol{\mu}$) between 0.4% to 0.7% ($\boldsymbol{\sigma}$) between 6.4% to 11%
[20]	Minimize the number of UAVs required to satisfy the timing constraints.	Naïve algorithm	assess the effectiveness of their proposed methods.	Euclidean distances= 10000 ×10000 grid.
[21]	Maximize the search space and minimize the terminal error.	Task Allocation algorithm.	Cooperative path planning for air–sea heterogeneous unmanned vehicles in a search-and-track mission was conducted through simulation results.	Search area =25 km × 25 km.
[22]	Controlling the three fundamental motions of UAVs: pitch, roll, and yaw.	Cuckoo Optimization Algorithm.	Novel selection process that employs the Cuckoo Optimization Algorithm (COA) and real measured resizable margins for goal detection.	Short distances= (0-0.1) criterion range Long distances= (0-50), (0-100), and (0-200) criteria ranges.

In [15], the study analysis revealed that safety is a more salient concern than privacy. Safety regulations focus on technical features, registration, certification, and differentiation by use case. Privacy rules tend to follow broader digital privacy guidelines, with some UAV-specific provisions. Comparisons with safety and privacy policies for automated vehicles and the smart grid highlight areas for harmonization and policy guidance. The study concludes with ten recommendations for future policy development.

In [16], UAV ion propulsion uses "ionic wind" generators, whose thrust characteristics and static aeroelastic properties were examined by researchers. The study examined various parameters, including electrode voltage, spacing, and emitter size, by integrating a two-dimensional gas discharge model and a gas dynamics model through simulation. Remarkably, the propulsion system affected drag (25.8%) significantly while contributing little to lift (12.2%). Optimizing these parameters can enhance UAV propulsion efficiency.

Table 3. UAV dataset descriptions along with a list of sources

Ref.	Datasets Descriptions	List of Sources
[13]	The dataset used in this study is generated from flight tests of a drone before and after the installation of a new route control system. The drone before the installation of this system used traditional route control methods. There are two types of planned routes: straight and curved, with the curve being a circular shape with a radius of 5 km. The deviation value between the actual route and the planned route was recorded every 150 seconds during the flight, and the control accuracy of the two methods on the route was compared.	[https://www.x-mol.net/paper/article/1726442685286076416], [https://link.springer.com/article/10.1007/s11831-022-09742-7], [https://www.mdpi.com/2072-4292/15/24/5758]
[14]	The data used in this study is derived from both theoretical calculations and experimental measurements.	[https://www.cambridge.org/core/journals/journal-of-fluid-mechanics/article/abs/timedomain-analysis-of-contrarotating-propeller-noise-wake-interaction-with-a-downstream-propeller-blade/A73229D6AD5A03857732F1CF80C42D6E], [https://asmedigitalcollection.asme.org/turbomachinery/article-abstract/136/1/011003/378049/Effect-of-Blade-Skew-Strategies-on-the-Operating?redirectedFrom=fulltext].
[15]	The data used in this study is derived from a comprehensive review of existing regulations and policies related to unmanned aerial vehicles (UAVs) in the mentioned jurisdictions.	[https://par.nsf.gov/biblio/10488283-safety-privacy-regulations-unmanned-aerial-vehicles-multiple-comparative-analysis], [https://www.mdpi.com/2313-576X/9/3/64].
[16]	The data used in this study is derived from both theoretical calculations and experimental measurements.	[https://www.x-mol.net/paper/article/1638755690286215168], [https://doaj.org/article/7451a78134b446d59c7473178d58c439].
[17]	The data used in this study is likely derived from a comprehensive review of existing literature on swarming drones and an experimental survey conducted among an academic population.	[https://research.abo.fi/en/publications/swarms-of-unmanned-aerial-vehicles-a-survey].
[18]	The data used in this study is derived from both theoretical calculations and experimental measurements.	[https://link.springer.com/article/10.1007/s42235-024-00486-7].
[19]	The data used in this study is derived from both theoretical calculations and experimental measurements.	[https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/495499/1/1-s2.0-S0005109821003101-main.pdf].
[20]	Various missions carried out by Unmanned Aerial Vehicles (UAVs) that are concerned with permanent monitoring of a predefined set of ground targets under relative deadline constraints.	[https://people.mpi-sws.org/~joel/publications/UAV-journal19.pdf], [https://link.springer.com/chapter/10.1007/978-3-319-33954-2_10].
[21]	A search-and-track (SAT) mission for an underwater target, implemented by combining an unmanned aerial vehicle (UAV), an unmanned surface vehicle (USV), and an autonomous underwater vehicle (AUV).	
[22]	A research work that evaluates the PID criteria for UAVs observation and tracking head within resizable selection by COA	[https://dr.ntu.edu.sg/bitstream/10356/147360/2/FINAL%20VERSION.pdf]. [https://data.mendeley.com/datasets/kjnsfwxwr9/1].

In [17], authors focus on swarming drones and their core characteristics. It highlights the functionality, challenges, and importance of drones. Additionally, survey results from an academic population demonstrate that swarming drones are a fundamental agenda for the future and will likely be widely adopted over time. Understanding these technological advancements and raising public awareness are crucial for responsible deployment.

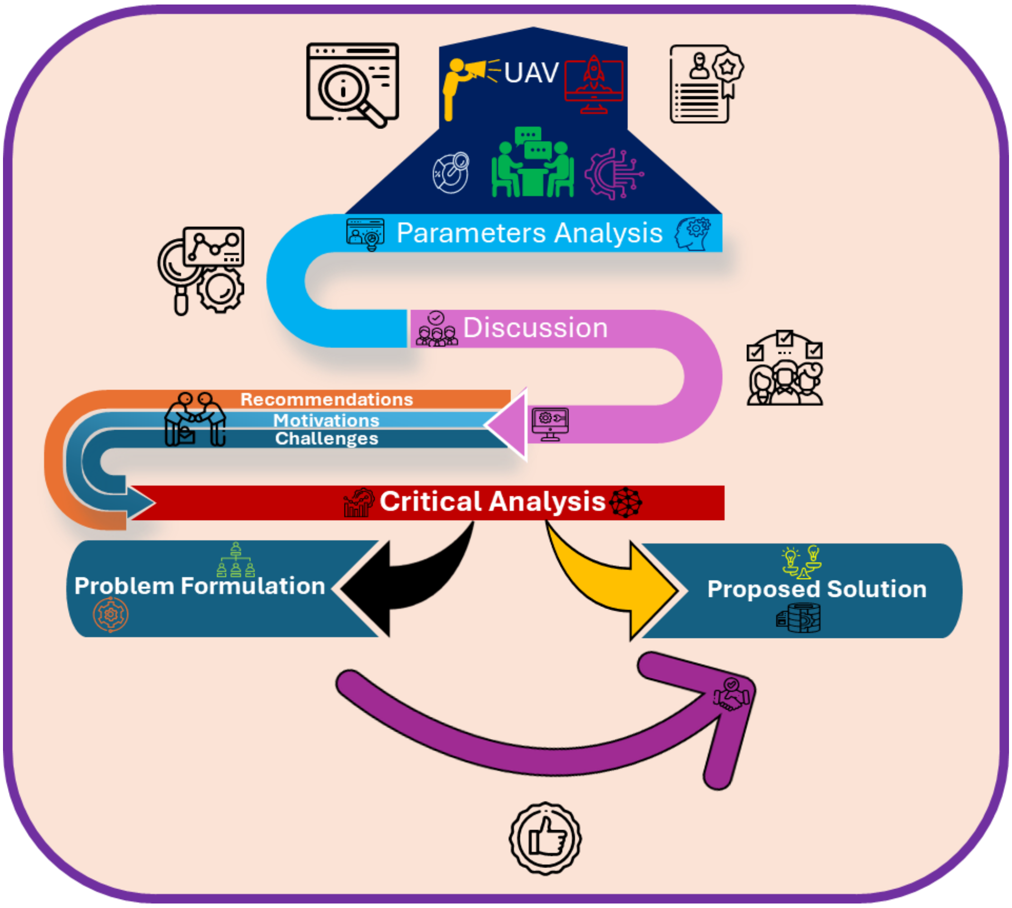

Fig. 9. Discussion flow method

To reduce aerodynamic resistance, the efficient low drag generation techniques discussed in [18] are used. Model Predictive Control (MPC) algorithms predict future states and modify control inputs accordingly, helping to achieve optimal vehicle behavior. The design process also pays attention to the production of hydrodynamic forces and fluid structure interaction. Computational simulations, rigorous experimental testing and theoretical calculations make it possible to reach a design ratio of 75 – 100%. This all-encompassing strategy ensures that automobiles are dependable, dependable, and efficient too.

In [19] researchers looked at fluid structure interaction, hydrodynamic force production (nonlinear and linear), nonlinear model predictive control, and model predictive control. To enhance performance and flexibility of hybrid UAVs, these domains employed the features of both fixed wing (like airplanes) and rotary wing (like helicopters). Promising results were obtained from the real-world flight experiments: standard deviation (σ) was upper bounded by 11% and lower bounded by 6.4% and average efficiency improvement (μ) was between 0.4% and 0.7%.

In [20], the study's findings and discussion on UAV's number reduction in order to meet timing requirements are presented. Part of this was done by scholars looking at a naïve algorithm and seeing how the solutions they suggested helped improve this. Their particular case of interest was in Euclidean distances in a 10,000 × 10,000 grid. The objective was to deploy UAV within time constraints for optimizing. By deriving different strategies, they try to identify effective solutions to reducing the total number of UAVs needed to complete the task.

In [21], the cooperative path planning for heterogeneous air-sea unmanned vehicles in the search and track mission problem was to maximize search space while minimizing terminal error.

Simulation was performed within a 25 km × 25 km search area using a Task Allocation algorithm. The objective of the outcomes was to maximize resource distribution and improve mission effectiveness.

Pitch, roll, and yaw are the three basic motions that UAVs can perform. In [22], researchers investigated these motions. They looked into ways to make these motions as precise as possible while in flight. The study also presented the COA, which was motivated by the behavior of cuckoo birds. Their egg-laying process is modeled by COA, where each nest stands for a potential solution. The algorithm's efficiency and convergence were improved by applying it to different optimization problems. Additionally, the study used a novel COA-based selection process that took into account both long (from 0-200 to 0-100) and short (from 0-0.1) distances. Measuring resizable margins for efficient goal detection was the aim.

The development of UAVs is greatly aided by the application of ML and artificial intelligence (AI). UAV can sense objects, navigate without intervention off their own back, avoid obstacles, and take real time decisions. By combining a mix of human expertise and AI driven capabilities, drones can perform demanding work across a variety of industries including defense, precision agriculture, environmental monitoring and disaster response. This article shows the combination of AI/ML and UAV technology is expanding application scope and driving new innovation. In the goal, the UAV system aims to provide the drones with precise route control. Probably using optimization techniques, but it's still not slimming. These algorithms use to arrive at which flight route will be the best for whatever variables that include fuel efficiency, obstacles, weather, etc. The objective is to improve the accuracy and stability at high speeds when performing flight tests. It is trying to improve the UAV route control system through the technology called Route Control for UAVs. Using the SIMPLE algorithm, the route execution and planning probably become better. By applying the machine learning techniques, the system can improve the route control accuracy and thus enhance the UAV operations reliability and quality.

Regulations Concerning Safety and Privacy: Evaluation of these regulations requires analysis of these intricate legal, policy structures. Optimization algorithms will be used to compare and evaluate different regulations to find the best possible operational efficiency and to be certain of compliance. While Aeroelastic Properties of Ion Propulsion UAVs, Understanding the behavior of propulsion systems in ion propulsion UAVs requires sophisticated analysis. Fluid-solid interaction techniques, likely optimized through ML or numerical methods, help identify aeroelastic properties. The reported accuracy metrics—elastic state (12.2%) and drag coefficient (25.8%)—highlight the importance of precise modeling. With the Swarming Drones Technology and Perception: Swarm intelligence algorithms play a pivotal role in coordinating large groups of drones. These algorithms optimize communication, navigation, and collaboration among individual drones, leading to improved technology and public perception of swarming capabilities.

When the Robust Optimization for Vehicle Design and Components designed a combination of techniques—efficient low drag generation, model predictive control, hydrodynamic forces production, and fluid-structure interaction—is employed. These ML and optimization methods help achieve optimal designs, validated through theoretical calculations, simulations, and experiments. While Hybrid UAVs Combining Rotary-Wing and Fixed-Wing Capabilities for combining rotary-wing and fixed-wing capabilities in hybrid UAVs likely involves optimization to balance flight modes, energy efficiency, and maneuverability. By Minimizing UAVs for Timing Constraints for Optimization algorithms can minimize the number of UAVs needed to meet timing constraints. By strategically deploying fewer UAVs without compromising mission objectives, operational costs can be reduced. In search-based applications, ML and optimization techniques maximize exploration while minimizing error. Whether it's search-and-rescue missions or exploration, these algorithms enhance efficiency and accuracy. The Controlling Fundamental UAV Motions (Pitch, Roll, Yaw): Model predictive control, hydrodynamic forces production, fluid-structure interaction, and nonlinear model predictive control contribute to precise motion control. Stable flight and responsiveness are guaranteed by these algorithms.

3.1. Recommendations

Since this study aims at improving the accuracy and stability of UAVs flight paths, it uses WSNs and the physical simulation techniques [23]-[29]. As in WSN, in WSNs distributed sensors collaborate to process and sense data collectively. These networks are indispensable in many applications, such as environmental behavior analysis, smart city development and structural health monitoring [30]-[38]. The integration of WSNs with physical simulation models gives the researchers additional tools for evaluating UAV flight paths. These simulation models allow them to forecast performance, optimize the routes, and interpret system behavior much simpler than the costly real-world experiments will. According to the study, UAV flight paths can be more accurate and stable if physical simulation and WSNs are combined. These outcomes demonstrate how much successful this strategy is, which makes it a good suggestion for UAV control systems in [13]. A different study for a dataset on UAV rotor systems [14] had suggested SOLVER algorithm to be used for this. The SIMPLE algorithm [39]-[50] is one that is proficient in anticipating system behavior. And the results suggest it is more accurate than experimental measurements for making predictions. While the particular use and advantages of the SIMPLE algorithm are not explored here, it is clear that the SIMPLE algorithm has potential for improving UAV rotor system predictions. The authors in [15] discovered that safety is a greater concern than privacy for UAVs. Some technical safety features such as redundancy, robustness and fail-safe mechanisms should be given increased priority in safety regulations. A certification and registration procedure for UAV operators to provide a guarantee that companies operating them adhere to safety regulations. Set safety standards differentially, based on which use cases they are for (drones used for recreational activities versus commercially).

UAV privacy laws ought to be consistent with more general digital privacy laws. Incorporate clauses unique to UAVs to handle privacy issues pertaining to information sharing, data collection, and surveillance. Examine and contrast UAV privacy and safety policies with those of automated cars and the smart grid. Determine which areas can benefit from harmonizing regulations to increase overall efficacy. Provide precise policy guidelines to handle trade-offs between privacy and safety. The last ten practical recommendations put the study to an end with purpose to help policymakers to create effective regulations in this area [51]-[60]. Finally, the study highlights the need to strike a tradeoff between protecting users' privacy and providing safety to UAV operations. The analysis in [16], has looked at the static aeroelastic properties and thrust characteristics of “ionic wind” generators used in UAV ion propulsion. Their simulation model, based on a gas dynamics model coupled with a two-dimensional gas discharge model, allowed them to study the key parameters namely the size of emitter, the electrode voltage and the spacing. Interestingly, the propulsion system contributed minimally to lift, 12.2%, but significantly reduced drag by 25.8%.

To improve the efficiency of UAV propulsion, the authors suggest maximizing these variables. Son compared ion propulsion to conventional chemical rockets in that it is a slower and more efficient means of propulsion for deep space exploration, a potentially critical technology. Additionally, the implications of the authors' findings should be analyzed in cases where these optimizations are practical to apply to existing UAV designs. In [17], writers explore the idea of swarming drones, how they operate, their primary traits, practicality, difficulties, and of course, general significance. Remarkably, survey responses from a population of academics highlight the importance of swarming drones as a key priority for the future. In order to enable the responsible deployment of swarming drone systems, the study suggests gaining an understanding of these technological advancements and increasing public awareness. Investigating the best decision-making techniques for Unmanned Aerial Systems (UAS) in dynamic environments is crucial as swarming technology advances. Wargames and machine learning approaches can help optimize UAS decision-making procedures, guaranteeing effective and efficient swarm behavior [61]-[72]. The first five studies were included in the recommendations as shown in Fig. 10, and the authors insights help shape the future of swarming technology and its responsible integration into various applications.

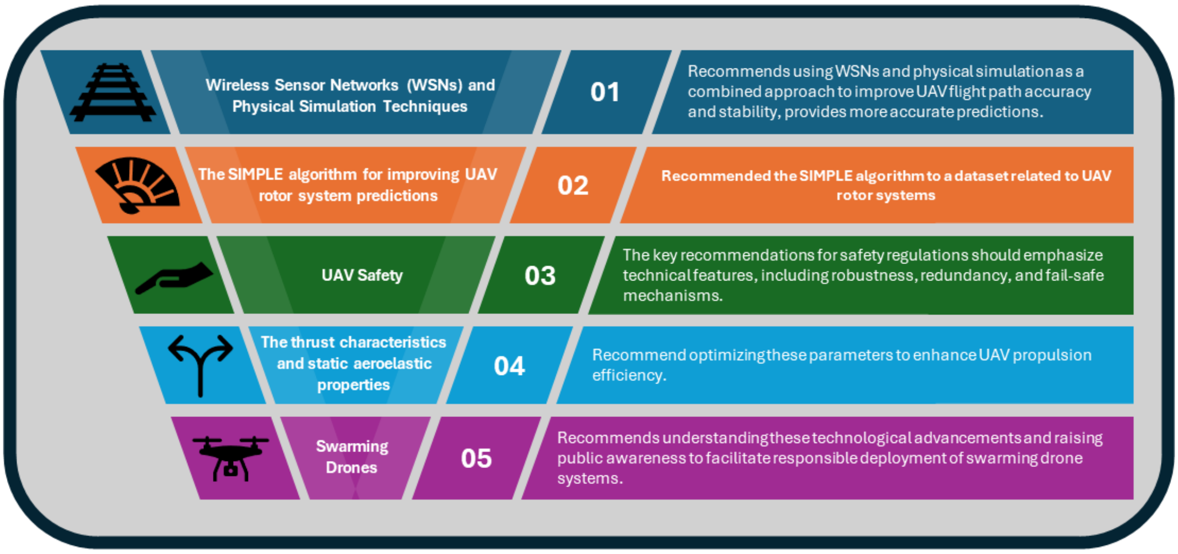

Fig. 10. The first five studies for recommendations

To lessen aerodynamic resistance, as in [18], the authors investigated effective low drag generation techniques. Model Predictive Control (MPC) algorithms help to attain optimal vehicle behavior by forecasting future states and making aperture control inputs. It further accounted for production of hydrodynamic forces and fluid structure interaction during design phase. The design ratio was achieved from 75 to 100 % through extensive experimental testing, computational simulations and theoretical calculations. Combined with that is the all-embracing strategy that guarantees cars are robust, are dependable as well as are efficient. The authors say more research is needed on MPC algorithms and their incorporation in useful car designs to improve overall performance. The importance of verifying these results in the real world via test & validation is also stressed to consider things like material properties, manufacturing tolerances and operational conditions. These factors provide the engineers a way to maximize the vehicle efficiency at the expense of the safety and dependability. In [19], researchers investigated a number of areas of importance in order to improve existing functionality and adaptability of hybrid UAV. Some of these elements included Model Predictive Control (MPC), Fluid-Structure Interaction, Hydrodynamic Forces Production, and non-linear Model Predictive Control. In order to optimize the UAV behavior, they used both the fixed wing (like airplanes) and the rotary wing (like helicopters) features.

Encouraging results were obtained from the practical flying trials, showing average efficiency enhancement (μ) between 0.4% and 0.7%. Additionally, the value of σ ranging from 6.4% to 11% was clear. The authors suggest doing more research on MPC algorithms and incorporating them into useful car design. Additionally, they emphasize the importance of validating these results through practical tests and practical validation, considering the available characteristics of material, manufacturing tolerances and operating circumstances. Taking these factors into account engineers can maximize vehicle efficiency, while maintaining safety and dependability. In the study [20], researchers examined to deploy UAV for data collection from Internet of Things (IoT) devices. The aim was to achieve a tight deadline while making sure that the data that we collected was accurate. Furthermore, data collection was required to last no longer than a given maximum data collection delay, such as 20 minutes, over the entire duration of each UAV's data collection tour, which included the flying and data collection phases. The study looked at two different approaches to the problem: Some of these include, one where UAVs could only send data to an IoT device if the Euclidean distance of the UAV to the device's location was under a wireless transmission range and one where UAVs need to fly to each location to collect data. For the first variant, the researchers give a 4 approximation algorithm: improvements from the most well-known approximation ratio, by showing a brand new 4 approximation algorithm. Additionally, they gave the first algorithm for constant factor approximation for the second variant. Experimental results confirmed that suggested algorithms used 11–19 percent fewer UAVs than the current approaches. The scientists also investigated a challenging mission in [21] where unmanned vehicles need to work together. In particular, a SAT mission was carried out, combining an unattended underwater vehicle (AUV), an unattended surface vehicle (USV) and an UAV for an underwater target [73]-[75]. The mission was divided into two sections: search phase and track phase. The aim of the search phase was to maximize the search space while in the track phase we minimized the terminal error. The study takes into account vehicle maneuverability and vehicle to vehicle communication range limitations.

The researchers created strategies based on asynchronous planning and random simulation experiments to address these issues. For both phases, they created a cooperative path planning algorithm that generated paths in either a distributed or centralized manner using the improved particle swarm optimization (IPSO) algorithm. The results of the simulation showed that the suggested approach handled a variety of scenarios well; in the SAT mission, the UAV & USV & AUV system outperformed the USV & AUV system. Ultimately, in [22], the researchers suggested optimizing pitch, roll, and yaw by utilizing the COA. Drawing inspiration from the Cuckoo bird's egg-laying habits, COA depicts solutions as nests. To improve efficiency and convergence, the study applied COA to a variety of optimization problems. Furthermore, the authors suggested a unique COA-based selection procedure that took into account both short (in the range of 0-0.1) and long distances (in the range of 0-100, 0-200, and 0-50). Measurement of resizable margins was made possible by this method, which helped UAV control achieve effective goal detection. The recommendations (the last five studies) are represented as in Fig. 11.

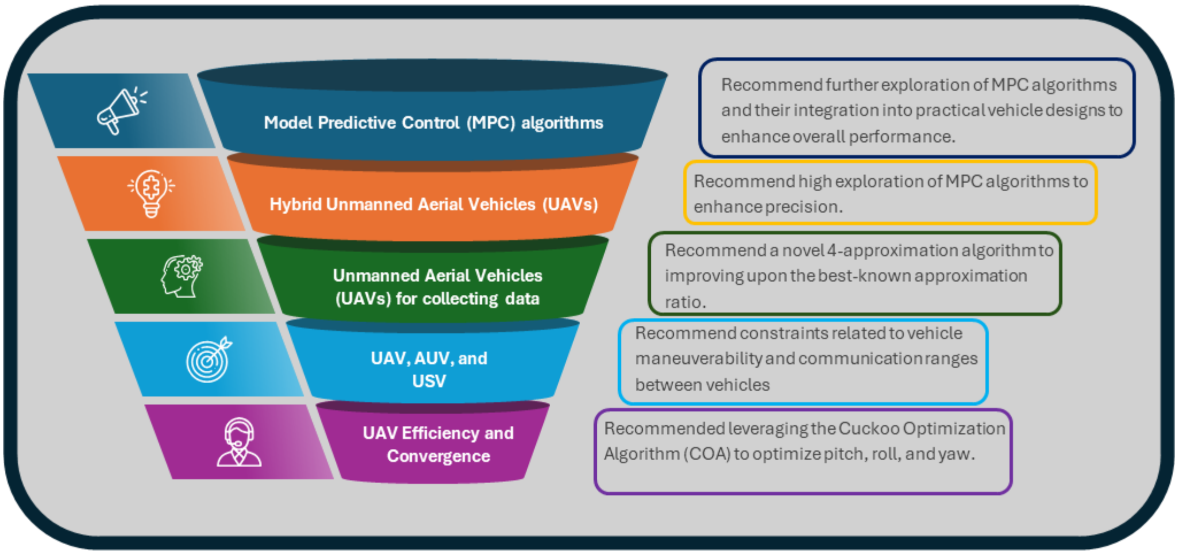

Fig. 11. The last five studies for recommendations

3.2. Motivations

In [13], the authors aimed at enhancing the accuracy and stability of the flight paths of UAVs. It suggested hybrid strategy which takes physical simulation methodology together with wireless sensor networks (WSNs) to achieve this. WSNs are important in many applications including environment behavior analysis, smart city development, and monitoring of structural health. Physical simulation models enable researchers to examine UAV flight paths efficiently, understand system behavior, and optimize routes and predict performance without the need for expensive real world experiments. This is demonstrated by the study's recommendation to use this strategy as a means to improve UAV control systems. One of the authors of the study [14] wondered himself whether the SIMPLE (Simple Iterative Method for Pressure-Linked Equations) algorithm could be applied to a dataset about rotor systems of UAVs. SIMPLE gave better prediction of system behavior in the experimental measurements, suggesting even more accurate predictions are possible. The study highlights its potential for improving predictions of UAV rotor system. Therefore, the study's authors were motivated to tackle the tradeoff between privacy and safety issues related to UAVs in [15].

Instead, they contended that safety regulations prioritised technical properties such as robustness, redundancy and fail safe mechanisms over the protection of privacy.

The research also brought out a registration and certification procedure for UAV operators to guarantee adherence to safety regulations. Use of UAV specific provisions to address privacy concerns associated with data collection, surveillance, and information sharing allows public policy makers to address privacy concerns and align privacy regulations with more general digital privacy guidelines. The thrust characteristics and static aeroelastic properties of "ionic wind" generators—used in ion propulsion for UAVs in [16] were investigated. Their simulation model combined a gas dynamics model with a two dimensional gas discharge model, so that they could study important variables such as size of emitter, electrode voltage and spacing. The propulsion system exhibited a 12.2% contribution to lift, yet a 25.8% reduction in drag. The reference [17] inspired the authors of the study to take a thorough look at the idea of swarming drones. The features that were essential for swarming drone systems, their practicality, difficulties, and general significance were stressed. Also noteworthy is that the results of a survey of academics contained in the report identified swarm drones as the most prominent key priority for the future. In [18] the authors want to take a closer look at efficient low drag generation approaches to reduce aerodynamic resistance. The first five studies for the challenges are shown in Fig. 12.

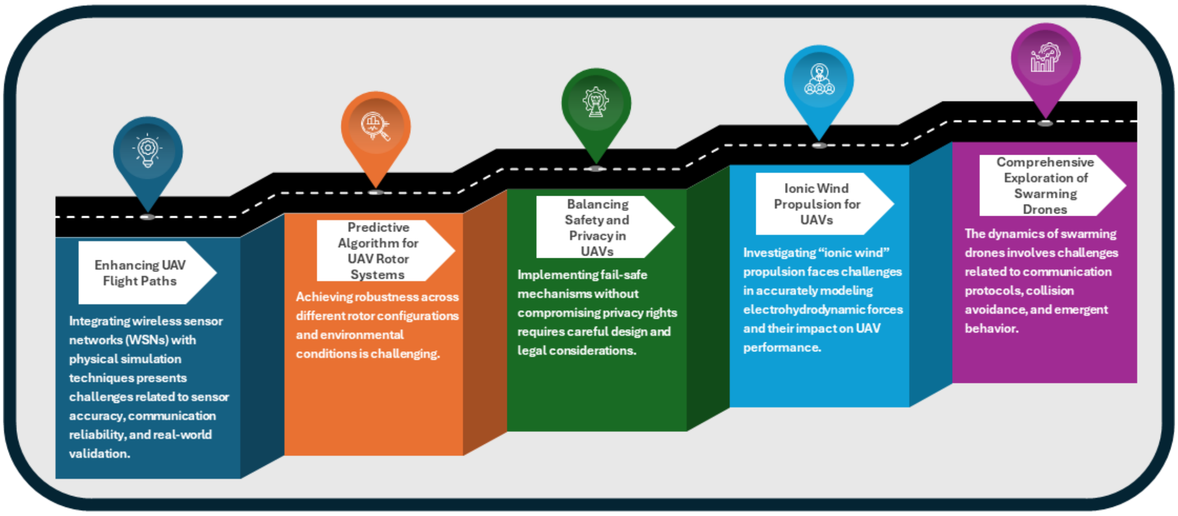

Fig. 12. The first five studies for challenges

Model Predictive Control (MPC) algorithms were used to forecast future conditions and modify control inputs so that the vehicle performs as ideal as possible. The research also closely studies the production of hydrodynamic forces and fluid structure interaction during the design phase. Apparently [19] wanted to investigate some important facets related to efficiency and adaptability of hybrid UAVs. Elements included Model Predictive Control (MPC), Fluid Structure Interaction, Hydrodynamic Forces Production, and Nonlinear Model Predictive Control. UAV features both fixed-wing (airplanes) and rotary-wing (helicopters) were used to try to obtain global maximum UAV behavior. In real world flight experiments, μ ranged between 0.4% and 0.7% and promising results were observed. Also, the standard deviation (σ) range was 6.4% to 11%. In [20] the authors are forced to talk about the usage of UAVs for collecting device data in the Internet of Things (IoT). The main goal was to finish it on time, making sure that the data we get is accurate. Motivated by a challenging mission requiring coordination among unmanned vehicles, the researchers in [21] proceed to investigate this. For example, they employed an AUV, an UAV, and an USV to target the underwater target of a SAT mission. The task was split into two stages: The track phase was to reduce terminal error and the search phase was to maximize search space. Inspired to investigate the use of the COA in unmanned vehicles to optimize roll, pitch, and yaw the authors of [22] used the COA to optimize roll, pitch, and yaw. The COA captures analogues from the Cuckoo bird and its egg laying habits, illustrating solutions as nests. The study employed the COA to several different optimization problems to improve efficiency and convergence. Additionally, the authors developed a novel COA based selection process that combines short (short distance between pair < 0.0 1) and large (larger distance between pair < 0 100, 0 200 or < 050) distances. By measuring resizable margins, this method allowed UAV control to achieve goal detection efficiently. Fig. 13 shows the last five studies for the challenges.

Fig. 13. The last five studies for challenges

3.2.1. Critical Analysis

Several critical studies of UAVs and their associated systems served as inspiration to write these studies. The following is a list of the points:

- Enhancing UAV Flight Paths [13]: The authors' goal was to increase UAV flight paths' accuracy and stability. As a result, they proposed combining physical simulation methods with wireless sensor networks (WSNs). WSNs and simulation models could be used to test flight paths, optimize routes, and predict performance without high cost real world experiments.
- Predictive Algorithm for UAV Rotor Systems [14]: The use of the SIMPLE (Simple Iterative Method for Pressure Linked Equations) algorithm on UAV rotor system was researched. The algorithm improved the system's performance, exceeding experimental measurements and demonstrating promise for the ability to make highly precise forecasts and providing features to improve rotor system capability.
- Balancing Safety and Privacy in UAVs [15]: The authors deliberate between of privacy and safety matters. They suggested that safety regulations emphasize technical features (redundancy, robustness, and fail-safe mechanisms). They also pushed for a certification and registration procedure for UAV operators to guarantee adherence to safety regulations and handle privacy concerns.
- Ionic Wind Propulsion for UAVs [16]: When using "ionic wind" generators for ion propulsion in UAVs, researchers investigated the thrust characteristics and static aeroelastic properties of these devices. They examined important parameters including emitter size, spacing, and electrode voltage using their simulation model. Although the propulsion system contributed modest lift (12.2%), it significantly impacted drag (25.8%).
- Comprehensive Exploration of Swarming Drones [17]: Authors highlighted the core characteristics, functionality, challenges, and importance of swarming drone systems. Survey results emphasized swarming drones as a fundamental agenda for the future.

- Efficient Low-Drag Generation Techniques [18]: The authors investigated minimizing aerodynamic resistance by utilizing Model Predictive Control (MPC) algorithms. MPC allows optimal vehicle behavior by predicting future states and adjusting control inputs. They also considered hydrodynamic forces production and fluid-structure interaction during design.
- Enhancing Hybrid UAV Performance [19]: Authors explored aspects to improve hybrid UAV performance. These included MPC, hydrodynamic forces production, fluid-structure interaction, and nonlinear MPC. By leveraging both rotary-wing and fixed-wing features, they aimed to optimize UAV behavior. Real-world flight experiments demonstrated efficiency improvements (μ) ranging from 0.4% to 0.7%, with a standard deviation (σ) between 6.4% and 11%.
- Data Collection from IoT Devices using UAVs [20]: Researchers addressed deploying UAVs for collecting fresh data from Internet of Things (IoT) devices within strict time constraints.
- Complex Cooperation Mission for Unmanned Vehicles [21]: The study involved cooperation among unmanned vehicles (UAV, USV, AUV) for a search-and-track mission. The search phase maximized the search space, while the track phase minimized terminal error.
- COA for UAV Control [22]: The authors investigated COA for UAV pitch, roll, and yaw optimization. COA modeled solutions as nests, drawing inspiration from the way cuckoo birds lay their eggs. The new selection procedure took both short- and long-range distances into account, which helped UAV control achieve efficient goal detection.

3.2.2. Problem Formulation

The problem statement can be summarized as follows:

- Enhancing UAV Flight Paths [13]: Improving UAV flight paths accuracy and stability was the issue. In order to assess flight paths, optimize routes, and forecast performance without the need for expensive in-person experiments, researchers set out to integrate wireless sensor networks (WSNs) with physical simulation techniques.
- Predictive Algorithm for UAV Rotor Systems [14]: Improving rotor system predictions was the issue. The goal of the study was to obtain accurate predictions beyond experimental measurements by utilizing the SIMPLE (Simple Iterative Method for Pressure-Linked Equations) algorithm on UAV rotor systems.
- Balancing Safety and Privacy in UAVs [15]: Managing the conflict between privacy and safety issues with UAVs was the challenge. While arguing for a registration and certification procedure for UAV operators to guarantee adherence to safety standards and handle privacy concerns, the authors suggested that safety regulations emphasize technical features.
- Ionic Wind Propulsion for UAVs [16]: When using "ionic wind" generators for ion propulsion in UAVs, researchers looked into the thrust characteristics and static aeroelastic properties of these devices. Understanding how emitter size, spacing, and electrode voltage affect propulsion efficiency was the challenge.
- Comprehensive Exploration of Swarming Drones [17]: Investigating swarming drone systems in-depth was the challenge. The writers underlined the significance of the fundamental traits, practicalities, and difficulties for the future.
- Efficient Low-Drag Generation Techniques [18]: The task at hand was to minimize the resistance caused by air. When designing, researchers took hydrodynamic force production and fluid-structure interaction into account by using Model Predictive Control (MPC) algorithms.
- Enhancing Hybrid UAV Performance [19]: By utilizing MPC, fluid-structure interaction, hydrodynamic forces production, and nonlinear MPC, the authors sought to enhance the

performance of hybrid UAVs. Standard deviation and efficiency improvements were shown in real-world flight experiments.

- Data Collection from IoT Devices using UAVs [20]: Using UAVs to gather new data from IoT devices under time constraints was a challenge.
- Complex Cooperation Mission for Unmanned Vehicles [21]: In order to optimize search space and reduce terminal error, researchers looked at collaboration between UAVs, USVs, and AUVs during a search-and-track mission.
- The COA for UAV Control [22]: COA, which is modeled after the egg-laying behavior of cuckoo birds, was used to optimize pitch, roll, and yaw in UAVs. The idea was to have an efficient way of the new selection procedure to detect goals.

3.2.3. Proposed Solution

The proposed solutions can be summarized as follows:

- Enhancing UAV Flight Paths [13]: Therefore, in order to better characterize impedance, researchers suggested combining physical simulation methods with wireless sensor networks (WSNs). This enabled them to examine UAV flight paths, improve them, predict outcomes, without spending huge amounts to incur their real-world trials. Precise path planning along with stability enhancements were possible using WSNs and simulation models in collaboration.
- Predictive Algorithm for UAV Rotor Systems [14]: Rotor system prediction using the SIMPLE algorithm was investigated. The motivation for using this algorithm was to generate predictions better than those generated from experimentation. The application of this strategy may improve rotor system dependability and performance.
- Balancing Safety and Privacy in UAVs [15]: Safety regulations speak of technical features (such as reliability, robustness, and fail-safe mechanics), the authors suggested. They also called for a UAV certification and registration procedure. The aim of this solution was to solve issues of privacy when collecting data and surveillance whilst conforming to safety regulations.
- Ionic Wind Propulsion for UAVs [16]: The thrust characteristics and aeroelastic properties of "ionic wind" generators, used in UAV ion propulsion, are examined by scholars. To obtain the solution, several important variables like electrode voltage, spacing, and emitter size needed to be correctly analyzed. Although the propulsion system contributed a small amount to lift, it dominated drag, providing valuable information on the direction of future design advancements.
- Comprehensive Exploration of Swarming Drones [17]: The authors say that swarming drone systems are important. Though it offered no specific solution, their thorough investigation was convincing of more study and development in this field, working with functional requirements, difficulties, and potential applications.
- Efficient Low-Drag Generation Techniques [18]: To reduce aerodynamic parasitic effects, researchers used Model Predictive Control (MPC) algorithms. The objective was to predict future states and adjust the control inputs such that vehicle behavior was maximized. Finally, by considering the production of hydrodynamic forces and fluid structure interaction during design efficiency improvements were further enhanced.
- Enhancing Hybrid UAV Performance [19]: The authors applied MPC, fluid structure interaction, production of hydrodynamic forces, and nonlinear MPC to improve hybrid UAV performance. Real world flight experiments validated the suggested solution with reductions in standard deviation and increases in efficiency.
- Data Collection from IoT Devices using UAVs [20]: As a part of the solution, UAVs were used to act as source of new data from IoT devices under temporal constraints. Precise technical information was withheld, but it was stressed that data would be 'acquired in a timely and accurate' fashion.

- Complex Cooperation Mission for Unmanned Vehicles [21]: For that, researchers studied how USVs, AUVs and UAVs would combine on a search and track mission. The suggested solution was designed to achieve efficiency in the teamwork aspect and optimize the search space from the search phase and to minimize the terminal error in the tracking phase.
- COA for UAV Control [22]: Optimizing pitch, roll, and yaw in UAVs was the solution, which involved using the COA. Drawing inspiration from the behavior of cuckoo birds, Solutions became COA's nests. The new selection procedure had been designed to provide a more efficient UAV control through the selection of objectives.

3.3. Challenges

The challenges can be presented as follows:

- Enhancing UAV Flight Paths [13]: Integrating wireless sensor network (WSN) with physical simulation techniques poses challenge of sensor accuracy, communication reliability and real-world validation. Smooth data exchange between nodes in a WSN and a precise model of complex flight dynamics are some of the most challenging tasks.
- Predictive Algorithm for UAV Rotor Systems [14]: An algorithm which consistently outperforms experimental measurements must address noise, uncertainties, and rotor behavior variations. However, robustness under varying environmental conditions and rotor configurations is difficult to attain.
- Balancing Safety and Privacy in UAVs [15]: Finding that perfect balance of privacy versus safety requires a lot of consideration of trade-offs. It takes careful planning and law considerations to put some things in place that can fail safe without infringing on the parties rights not to have their information shared.
- Ionic Wind Propulsion for UAVs [16]: Researching 'ionic wind' propulsion is difficult because it is difficult to accurately model electrohydrodynamic forces on UAVs and how these forces impact UAV performance. Although it is still difficult to lose lift while consuming the least amount of energy.
- Comprehensive Exploration of Swarming Drones [17]: Communication protocols, collision avoidance, and emergent behavior present challenges in our understanding of the dynamics of swarming drones. It's also challenging to guarantee adaptability and scalability in big swarms.
- Efficient Low-Drag Generation Techniques [18]: Turbulence modeling, control system robustness, and the complexity of fluid-structure interactions must all be taken into consideration in order to minimize aerodynamic resistance. It is difficult to perform at your best in a variety of flying situations.
- Enhancing Hybrid UAV Performance [19]: Nonlinear control techniques, balancing rotary-wing and fixed-wing features, and handling aerodynamic coupling are all necessary for optimizing hybrid UAV behavior. It's difficult to guarantee steady efficiency gains while preserving stability.
- Data Collection from IoT Devices using UAVs [20]: Managing dynamic IoT environments, energy efficiency, and synchronization are challenges when deploying UAVs for timely data collection. It's challenging to maintain data freshness under stringent time constraints.
- Complex Cooperation Mission for Unmanned Vehicles [21]: In a search-and-track mission, coordinating UAVs, USVs, and AUVs necessitates resolving communication lags, sensor fusion, and cooperative decision-making. There are challenges in balancing tracking accuracy with search efficiency.
- COA for UAV Control [22]: There are difficulties in handling multimodal optimization landscapes, convergence speed, and parameter tuning when using the COA. It is difficult to

ensure efficient goal detection while preventing early convergence. UAVs have a number of significant limitations with regards to practical implementation in a variety of application scenarios. The batteries limited power supply is a significant obstacle which limits flight endurance. Different battery designs using internal combustion engines or hybrid systems are examined to reduce this problem. Additionally, docked batteries (recharging or changing out) are a promising alternative. However, still there exists a need to enhance the flight autonomy, optimize the path planning, increase the battery endurance, and increase the payload carrying capacity for the UAV. Furthermore, UAVs have difficulties with communication protocols, the avoidance of collision, and existing behavior in swarm situations. Implementing fail safe mechanisms also requires careful design and legal considerations, and involves striking, at least, a balance between safety and privacy. Traditionally speaking such UAV research is motivated to surmount these obstacles and to realize the full potential of such machines in many different fields.

4. Conclusion

A systematic review of the UAV technology shows that UAVs are a very useful tool, but have lots of drawbacks. Flight endurance, however, is of particular importance because of the limited power supply of the battery. To solve this problem, researchers look at different battery designs, including internal combustion engines and hybrids. In addition, recharging or changing out of batteries via docking stations seems like a promising alternative. It also contains other challenges such as flight autonomy, path planning, battery endurance, and payload carrying capacity, must also be overcome by UAVs. Challenges in addition to such emergent behaviour in swarming scenarios and collision avoidance, and communication protocols are also present. The safety privacy ratio must be maintained, and that requires careful planning and legal considerations to implement fail safe mechanisms. Despite these drawbacks, however, the potential of UAVs in various fields has attracted much continued research attempts to realize it completely. A systematic review indicates that meta heuristic algorithms are a common optimization technique used for problem solving UAV path planning problems involving one or more objectives. However, since these algorithms have seen a massive improvement in UAV path planning optimization, problems inherent to such dynamic and complex environments as rescue missions, battlefields, mobile obstacle scenarios, and multi-UAV situations, are yet to be resolved. Additionally, one such meta heuristic algorithm that showed excellent potential to handle nonlinear optimization problem is the COA. Currently, researchers are developing UAVs to keep performance as well as privacy, safety and legal issues for consideration. Nowadays, UAVs are essential tools for the use in many areas, even beyond of the recreational use. By tackling issues with autonomy, battery life, and security, scientists can enable UAVs to reach their maximum potential. Integration of MCDM and optimization techniques further enhances their impact across a variety of applications increasing the utility and efficiency. Researchers and practitioners need to keep searching for innovative ways to trick and extend UAV technology.

Author Contribution: All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper.

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References

[1] M. Aljehani, M. Inoue, A. Watanbe, T. Yokemura, F. Ogyu, and H. Iida, “UAV communication system integrated into network traversal with mobility,” *SN Applied Sciences*, vol. 2, no. 1057, 2020, https://doi.org/10.1007/s42452-020-2749-5.

[2] A. Y. Alkayas, M. Chehadeh, A. Ayyad and Y. Zweiri, "Systematic Online Tuning of Multirotor UAVs for Accurate Trajectory Tracking Under Wind Disturbances and In-Flight Dynamics Changes," *IEEE Access*, vol. 10, pp. 6798-6813, 2022, https://doi.org/10.1109/ACCESS.2022.3142388.

[3] T. Jiang, J. Li, and K. Huang, "Longitudinal parameter identification of a small unmanned aerial vehicle based on modified particle swarm optimization," *Chinese Journal of Aeronautics*, vol. 28, no. 3, pp. 865-873, 2015, https://doi.org/10.1016/j.cja.2015.04.005.

[4] L. Zhi, W. Yong, "Fuzzy adaptive tracking control within the full envelope for an unmanned aerial vehicle," *Chinese Journal of Aeronautics*, vol. 27, no. 5, pp. 1273-1287, 2014, https://doi.org/10.1016/j.cja.2014.08.012.

[5] L. S. Uman, "Systematic reviews and meta-analyses," *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, vol. 20, no. 1, pp. 57-59, 2011, https://pmc.ncbi.nlm.nih.gov/articles/PMC3024725/.

[6] J. P. A. Ioannidis, "The mass production of redundant, misleading, and conflicted systematic reviews and meta-analyses," *The Milbank Quarterly*, vol. 94, no. 3, pp. 485-514, 2016, https://doi.org/10.1111/1468-0009.12210.

[7] L. Zhong, H. Yuqing, Y. Living, H. Jianda, "Control techniques of tilt rotor unmanned aerial vehicle systems: A review," *Chinese Journal of Aeronautics*, vol. 30, no. 1, pp. 135-148, 2017, https://doi.org/10.1016/j.cja.2016.11.001.

[8] S. Sai, A. Garg, K. Jhawar, V. Chamola and B. Sikdar, "A Comprehensive Survey on Artificial Intelligence for Unmanned Aerial Vehicles," *IEEE Open Journal of Vehicular Technology*, vol. 4, pp. 713-738, 2023, https://doi.org/10.1109/OJVT.2023.3316181.

[9] H. M. Jayaweera and S. Hanoun, "A Dynamic Artificial Potential Field (D-APF) UAV Path Planning Technique for Following Ground Moving Targets," *IEEE Access*, vol. 8, pp. 192760-192776, 2020, https://doi.org/10.1109/ACCESS.2020.3032929.

[10] H. A. Mwenegoha, T. Moore, J. Pinchin and M. Jabbal, "A Model-based Tightly Coupled Architecture for Low-Cost Unmanned Aerial Vehicles for Real-Time Applications," *IEEE Access*, 2020, https://doi.org/10.1109/ACCESS.2020.3038530.

[11] K. Shao, K. Huang, S. Zhen, H. Sun and R. Yu, "A Novel Approach for Trajectory Tracking Control of an Under-Actuated Quad-Rotor UAV," *IEEE/CAA Journal of Automatica Sinica*, vol. 11, no. 9, pp. 2030-2032, 2024, https://doi.org/10.1109/JAS.2016.7510238.

[12] D. L. D. Silva, R. Machado, O. L. Coutinho and F. Antreich, "A Soft-Kill Reinforcement Learning Counter Unmanned Aerial System (C-UAS) With Accelerated Training," *IEEE Access*, vol. 11, pp. 31496-31507, 2023, https://doi.org/10.1109/ACCESS.2023.3253481.

[13] Z. Xu, Y. Zhang, H. Chen, Y. Hu, and L. Wang, "Research on precise route control of unmanned aerial vehicles based on physical simulation systems," *Results in Physics*, vol. 56, p. 107200, 2024, https://doi.org/10.1016/j.rinp.2023.107200.

[14] R. Jung *et al.*, "The effect of blade skew on the interaction tones produced by a contra-rotating unmanned aerial vehicle rotor system," *Journal of Sound and Vibration*, vol. 572, p. 118186, 2024, https://doi.org/10.1016/j.jsv.2023.118186.

[15] D. Lee, D. J. Hess, and M. A. Heldeweg, "Safety and privacy regulations for unmanned aerial vehicles: A multiple comparative analysis," *Technology in Society*, vol. 71, p. 102079, 2022, https://doi.org/10.1016/j.techsoc.2022.102079.

[16] S. Hao, T. Ma, S. Chen, H. Ma, J. Xiang, and F. Ouyang, "Static aeroelasticity of the propulsion system of ion propulsion unmanned aerial vehicles," *Propulsion and Power Research*, vol. 12, no. 3, pp. 336-355, 2023, https://doi.org/10.1016/j.jppr.2023.01.001.

[17] A. Tahir, J. Böling, M. H. Haghbayan, H. T. Toivonen, and J. Plosila, "Swarms of Unmanned Aerial Vehicles - A Survey," *Journal of Industrial Information Integration*, vol. 16, p. 100106, 2019, https://doi.org/10.1016/j.jii.2019.100106.

[18] V. Raja, A. Prakash R, A. Kumar, and D. A. d. J. Pacheco, "Multi-disciplinary engineering design of a high-speed nature-inspired unmanned aquatic vehicle," *Ocean Engineering*, vol. 270, p. 113455, 2023, https://doi.org/10.1016/j.oceaneng.2022.113455.

[19] M. Allenspach and G. J. J. Ducard, "Nonlinear model predictive control and guidance for a propeller-tilting hybrid unmanned air vehicle," *Automatica*, vol. 132, p. 109790, 2021, https://doi.org/10.1016/j.automatica.2021.109790.

[20] N. Drucker, H. M. Ho, J. Ouaknine, M. Penn, and O. Strichman, "Cyclic-routing of Unmanned Aerial Vehicles," *Journal of Computer and System Sciences*, vol. 103, pp. 18-45, 2019, https://doi.org/10.1016/j.jcss.2019.02.002.

[21] C. Ke and H. Chen, "Cooperative path planning for air–sea heterogeneous unmanned vehicles using search-and-tracking mission," *Ocean Engineering*, vol. 262, p. 112020, 2022, https://doi.org/10.1016/j.oceaneng.2022.112020.

[22] N. Basil and H. M. Marhoon, "Towards evaluation of the PID criteria based UAVs observation and tracking head within resizable selection by COA algorithm," *Results in Control and Optimization*, vol. 12, p. 100279, 2023, https://doi.org/10.1016/j.rico.2023.100279.

[23] Y. Liu, "EURO Journal on Transportation and Logistics A multi-agent semi-cooperative unmanned air traffic management model with separation assurance," *EURO Journal on Transportation and Logistics*, vol. 10, p. 100058, 2021, https://doi.org/10.1016/j.ejtl.2021.100058.

[24] J. Jordan, "The future of unmanned combat aerial vehicles: An analysis using the Three Horizons framework," *Futures*, vol. 134, p. 102848, 2021, https://doi.org/10.1016/j.futures.2021.102848.

[25] L. Zhang, S. Wu, and C. Tang, "Cooperative positioning of underwater unmanned vehicle clusters based on factor graphs," *Ocean Engineering*, vol. 287, p. 115854, 2023, https://doi.org/10.1016/j.oceaneng.2023.115854.

[26] N. Basil, H. M. Marhoon, M. R. Hayal, E. E. Elsayed, I. Nurhidayat, and M. A. Shah, "Black-hole optimisation algorithm with FOPID-based automation intelligence photovoltaic system for voltage and power issues," *Australian Journal of Electrical and Electronics Engineering*, vol. 21, no. 2, pp. 115-127, 2024, https://doi.org/10.1080/1448837X.2024.2308415.

[27] M. Vierhauser, A. Garmendia, M. Stadler, M. Wimmer, and J. Cleland-huang, "The Journal of Systems & Software GRuM - A flexible model-driven runtime monitoring framework and its application to automated aerial and ground vehicles ☆," *Journal of Systems and Software*, vol. 203, p. 111733, 2023, https://doi.org/10.1016/j.jss.2023.111733.

[28] N. Basil and H. M. Marhoon, "Selection and evaluation of FOPID criteria for the X-15 adaptive flight control system (AFCS) via Lyapunov candidates: Optimizing trade-offs and critical values using optimization algorithms," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 6, p. 100305, 2023, https://doi.org/10.1016/j.prime.2023.100305.

[29] S. Poudel and S. Moh, "Task assignment algorithms for unmanned aerial vehicle networks: A comprehensive survey ☆," *Vehicular Communications*, vol. 35, p. 100469, 2022, https://doi.org/10.1016/j.vehcom.2022.100469.

[30] J. Xia, Y. Luo, Z. Liu, Y. Zhang, H. Shi, and Z. Liu, "Cooperative multi-target hunting by unmanned surface vehicles based on multi-agent reinforcement learning," *Defence Technology*, vol. 29, pp. 80-94, 2023, https://doi.org/10.1016/j.dt.2022.09.014.

[31] S. Mishra, "Heliyon Internet of things enabled deep learning methods using unmanned aerial vehicles enabled integrated farm management," *Heliyon*, vol. 9, no. 8, p. e18659, 2023, https://doi.org/10.1016/j.heliyon.2023.e18659.

[32] I. Colomina and P. Molina, "ISPRS Journal of Photogrammetry and Remote Sensing Unmanned aerial systems for photogrammetry and remote sensing: A review," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 92, pp. 79-97, 2014, https://doi.org/10.1016/j.isprsjprs.2014.02.013.

[33] N. Basil, M. E. Alqaysi, M. Deveci, A. S. Albahri, O. S. Albahri, and A. H. Alamoodi, "Evaluation of autonomous underwater vehicle motion trajectory optimization algorithms," *Knowledge-Based Systems*, vol. 276, p. 110722, 2023, https://doi.org/10.1016/j.knosys.2023.110722.

[34] G. Wu, X. Gao, X. Fu, K. Wan, and R. Di, "Mobility control of unmanned aerial vehicle as communication relay in airborne multi-user systems," *Chinese Journal of Aeronautics*, vol. 32, no. 6, pp. 1520-1529, 2019, https://doi.org/10.1016/j.cja.2019.02.010.

[35] B. Li, Y. He, J. Han, and J. Xiao, "A new modeling scheme for powered parafoil unmanned aerial vehicle platforms: Theory and experiments," *Chinese Journal of Aeronautics*, vol. 32, no. 11, pp. 2466-2479, 2019, https://doi.org/10.1016/j.cja.2019.04.001.

[36] X. Wang, Y. Zhang, L. Wang, and D. Lu, "Robustness evaluation method for unmanned aerial vehicle swarms based on complex network theory," *Chinese Journal of Aeronautics*, vol. 33, no. 1, pp. 352-364, 2020, https://doi.org/10.1016/j.cja.2019.04.025.

[37] K. C. U. Obias, M. F. Q. Say, E. A. V. Fernandez, A. Y. Chua and E. Sybingco, "A Study of the Interaction of Proportional-Integral- Derivative (PID) Control in a Quadcopter Unmanned Aerial Vehicle (UAV) Using Design of Experiment," *2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, pp. 1-4, 2019, https://doi.org/10.1109/HNICEM48295.2019.9072806.

[38] Z. Yu, Y. Zhang, B. Jiang, J. Fu, and Y. Jin, "REVIEW A review on fault-tolerant cooperative control of multiple unmanned aerial vehicles," *Chinese Journal of Aeronautics*, vol. 35, no. 1, pp. 1-18, 2022, https://doi.org/10.1016/j.cja.2021.04.022.

[39] D. Zhao *et al.*, "A multiscale transform denoising method of the bionic polarized light compass for improving the unmanned aerial vehicle navigation accuracy," *Chinese Journal of Aeronautics*, vol. 35, no. 4, pp. 400-414, 2022, https://doi.org/10.1016/j.cja.2021.04.028.

[40] A. F. Mohammed, H. M. Marhoon, N. Basil, and A. Ma'arif, "A New Hybrid Intelligent Fractional Order Proportional Double Derivative+ Integral (FOPDD+ I) Controller with ANFIS Simulated on Automatic Voltage Regulator System," *International Journal of Robotics and Control Systems*, vol. 4, no. 2, pp. 463-479, 2024, https://doi.org/10.31763/ijrcs.v4i2.1336.

[41] W. Lin, L. Li, Y. Liu, Y. He, and Y. Liu, "Timeliness optimization of unmanned aerial vehicle lossy communications for internet-of-things," *Chinese Journal of Aeronautics*, vol. 36, no. 6, pp. 249-255, 2023, https://doi.org/10.1016/j.cja.2022.08.022.

[42] N. Basil and H. M. Marhoon, "Correction to: selection and evaluation of FOPID criteria for the X-15 adaptive flight control system (AFCS) via Lyapunov candidates: Optimizing trade-offs and critical values using optimization algorithms," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 8, p. 100589, 2024, https://doi.org/10.1016/j.prime.2024.100589.

[43] L. Wang, J. Wang, J. Ai, H. Liu, and T. Yue, "Suggestions for flying qualities requirements of autonomous control unmanned combat aerial vehicles," *Chinese Journal of Aeronautics*, vol. 36, no. 11, pp. 42-57, 2023, https://doi.org/10.1016/j.cja.2023.05.023.

[44] N. Basil, H. M. Marhoon, and A. R. Ibrahim, "A new thrust vector-controlled rocket based on JOA using MCDA," *Measurement: Sensors*, vol. 26, p. 100672, 2023, https://doi.org/10.1016/j.measen.2023.100672.

[45] I. Elkhrachy, "Accuracy Assessment of Low-Cost Unmanned Aerial Vehicle (UAV) Photogrammetry," *Alexandria Engineering Journal*, vol. 60, no. 6, pp. 5579-5590, 2021, https://doi.org/10.1016/j.aej.2021.04.011.

[46] A. O. Khadidos, I. Al-darraji, A. O. Khadidos, and G. Tsaramirsis, "A new tilted aerial robotic platform: Modeling and control," *Alexandria Engineering Journal*, vol. 84, pp. 126-137, 2023, https://doi.org/10.1016/j.aej.2023.11.007.

[47] A. F. Mohammed *et al.*, "Selection and Evaluation of Robotic Arm based Conveyor Belts (RACBs) Motions: NARMA (L2)-FO (ANFIS) PD-I based Jaya Optimization Algorithm," *International Journal of Robotics and Control Systems*, vol. 4, no. 1, pp. 262-290, 2024, https://doi.org/10.31763/ijrcs.v4i1.1243.

[48] C. Ramos-romero, N. Green, A. J. Torija, and C. Asensio, "On-field noise measurements and acoustic characterisation of multi-rotor small unmanned aerial systems," *Aerospace Science and Technology*, vol. 141, p. 108537, 2023, https://doi.org/10.1016/j.ast.2023.108537.

[49] F. S. Raheem and N. Basil, "Automation intelligence photovoltaic system for power and voltage issues based on Black Hole Optimization algorithm with FOPID," *Measurement: Sensors*, vol. 25, p. 100640, 2023, https://doi.org/10.1016/j.measen.2022.100640.

[50] H. M. Marhoon, N. Basil, and B. B. Q. Elias, "Design and Manufacturing of an Efficient Low-Cost Fire Surveillance System Based on GSM Communications and IoT Technology," *Proceedings of Third International Conference on Computing and Communication Networks*, pp. 77-93, 2023, https://doi.org/10.1007/978-981-97-0892-5_6.

[51] D. Aláez *et al.*, "Digital twin modeling of open category UAV radio communications: A case study," *Computer Networks*, vol. 242, p. 110276, 2024, https://doi.org/10.1016/j.comnet.2024.110276.

[52] H. M. Marhoon, N. Basil, and A. Ma'arif, "Exploring Blockchain Data Analysis and Its Communications Architecture: Achievements, Challenges, and Future Directions: A Review Article," *International Journal of Robotics and Control Systems*, vol. 3, no. 3, pp. 609-626, 2023, https://doi.org/10.31763/ijrcs.v3i3.1100.

[53] L. Yang, S. Li, C. Zhu, A. Zhang, and Z. Liao, "Advanced Engineering Informatics Spatio-temporal correlation-based multiple regression for anomaly detection and recovery of unmanned aerial vehicle flight data," *Advanced Engineering Informatics*, vol. 60, p. 102440, 2024, https://doi.org/10.1016/j.aei.2024.102440.

[54] N. B. Mohamadwasel and S. Kurnaz, "Implementation of the parallel robot using FOPID with fuzzy type-2 in use social spider optimization algorithm," *Applied Nanoscience*, vol. 13, pp. 1389-1899, 2024, https://doi.org/10.1007/s13204-024-03013-6.

[55] M. Mammarella, L. Comba, A. Biglia, F. Dabbene, P. Gay, "ScienceDirect Cooperation of unmanned systems for agricultural applications: A case study in a vineyard," *Biosystems Engineering*, vol. 223, pp. 81-102, 2021, https://doi.org/10.1016/j.biosystemseng.2021.12.010.

[56] H. M. Marhoon, A. I. Alanssari, and N. Basil, "Design and Implementation of an Intelligent Safety and Security System for Vehicles Based on GSM Communication and IoT Network for Real-Time Tracking," *Journal of Robotics and Control*, vol. 4, no. 5, pp. 708-718, 2023, https://doi.org/10.18196/jrc.v4i5.19652.

[57] H. M. Marhoon, N. Basil, and A. F. Mohammed, "Medical Defense Nanorobots (MDNRs): a new evaluation and selection of controller criteria for improved disease diagnosis and patient safety using NARMA(L2)-FOP + D(ANFIS)μ – Iλ-based Archimedes Optimization Algorithm," *International Journal of Information Technology*, 2024, https://doi.org/10.1007/s41870-023-01724-7.

[58] J. Steenvoorden, H. Bartholomeus, and J. Limpens, "International Journal of Applied Earth Observations and Geoinformation Less is more: Optimizing vegetation mapping in peatlands using unmanned aerial vehicles (UAVs)," *International Journal of Applied Earth Observation and Geoinformation*, vol. 117, p. 103220, 2023, https://doi.org/10.1016/j.jag.2023.103220.

[59] V. Chamola, P. Kotesh, A. Agarwal, and N. Gupta, "Ad Hoc Networks A Comprehensive Review of Unmanned Aerial Vehicle Attacks and Neutralization Techniques," *Ad Hoc Networks*, vol. 111, p. 102324, 2021, https://doi.org/10.1016/j.adhoc.2020.102324.

[60] N. Basil and A. Ma'arif, "NB Theory with Bargaining Problem: A New Theory," *International Journal of Robotics and Control Systems*, vol. 2, no. 3, pp. 606-609, 2022, https://doi.org/10.31763/ijrcs.v2i3.798.

[61] Saifullah, Z. Ren, K. Hussain, and M. Faheem, "Ad Hoc Networks K-means online-learning routing protocol (K-MORP) for unmanned aerial vehicles (UAV) adhoc networks," *Ad Hoc Networks*, vol. 154, p. 103354, 2024, https://doi.org/10.1016/j.adhoc.2023.103354.

[62] A. M. Raivi and S. Moh, "A comprehensive survey on data aggregation techniques in UAV-enabled Internet of things," *Computer Science Review*, vol. 50, p. 100599, 2023, https://doi.org/10.1016/j.cosrev.2023.100599.

[63] T. Ojha, T. P. Raptis, A. Passarella, and M. Conti, "Wireless power transfer with unmanned aerial vehicles: State of the art and open challenges," *Pervasive and Mobile Computing*, vol. 93, p. 101820, 2023, https://doi.org/10.1016/j.pmcj.2023.101820.

[64] N. Basil, H. M. Marhoon, S. Gokulakrishnan, and D. Buddhi, "Jaya optimization algorithm implemented on a new novel design of 6-DOF AUV body: a case study," *Multimedia Tools and Applications*, 2022, https://doi.org/10.1007/s11042-022-14293-x.

[65] F. Saeed *et al.*, "Smart delivery and retrieval of swab collection kit for COVID-19 test using autonomous Unmanned Aerial Vehicles," *Physical Communication*, vol. 48, p. 101373, 2021, https://doi.org/10.1016/j.phycom.2021.101373.

[66] G. Guido, V. Gallelli, D. Rogano, and A. Vitale, "International Journal of Transportation Evaluating the accuracy of vehicle tracking data obtained from Unmanned Aerial Vehicles," *International Journal of Transportation Science and Technology*, vol. 5, no. 3, pp. 136-151, 2017, https://doi.org/10.1016/j.ijtst.2016.12.001.

[67] B. S. Freeman, J. Ahmad, A. Matawah, M. Al, B. Gharabaghi, and J. Thé, "International Journal of Transportation Vehicle stacking estimation at signalized intersections with unmanned aerial systems Ministry of Interior," *International Journal of Transportation Science and Technology*, vol. 8, no. 2, pp. 231-249, 2019, https://doi.org/10.1016/j.ijtst.2018.12.002.

[68] H. M. Marhoon, A. R. Ibrahim, and N. Basil, "Enhancement of Electro Hydraulic Position Servo Control System Utilising Ant Lion Optimiser," *International Journal of Nonlinear Analysis and Applications*, vol. 12, no. 2, pp. 2453-2461, 2021, https://doi.org/10.22075/ijnaa.2021.5387.

[69] B. Qian, N. Al, and B. Dong, "New technologies for UAV navigation with real-time pattern recognition," *Ain Shams Engineering Journal*, vol. 15, no. 3, p. 102480, 2024, https://doi.org/10.1016/j.asej.2023.102480.

[70] B. Yu, H. Jeon, H. Bang, S. Soo, and J. Min, "Fender segmentation in unmanned aerial vehicle images based on densely connected receptive fi eld block," *International Journal of Naval Architecture and Ocean Engineering*, vol. 14, p. 100472, 2022, https://doi.org/10.1016/j.ijnaoe.2022.100472.

[71] A. R. Ibrahim, N. Basil, and M. I. Mahdi, "Implementation enhancement of AVR control system within optimization techniques," *International Journal of Nonlinear Analysis and Applications*, vol. 12, no. 2, pp. 2021-2027, 2021, https://doi.org/10.22075/ijnaa.2021.5339.

[72] P. Sheng-zhao, Z. Hua-liang, D. Yu-long, B. Wen-qiang, and F. Jun-liang, "Nitrogen nutrition diagnosis for cotton under mulched drip irrigation using unmanned aerial vehicle multispectral images," *Journal of Integrative Agriculture*, vol. 22, no. 8, pp. 2536-2552, 2023, https://doi.org/10.1016/j.jia.2023.02.027.

[73] N. B. Mohamadwasel, "Rider Optimization Algorithm implemented on the AVR Control System using MATLAB with FOPID," *IOP Conference Series: Materials Science and Engineering*, vol. 928, no. 3, p. 032017, 2020, https://doi.org/10.1088/1757-899X/928/3/032017.

[74] H. M. Marhoon, N. Qasem, N. Basil, and A. R. Ibrahim, "Design and Simulation of a Compact Metal-Graphene Frequency Reconfigurable Microstrip Patch Antenna with FSS Superstrate for 5G Applications," *International Journal on Engineering Applications*, vol. 10, no. 3, pp. 193-201, 2022, https://doi.org/10.15866/irea.v10i3.21752.

[75] Z. Jin, D. Li, and J. Xiang, "Robot Pilot: A New Autonomous System Toward Flying Manned Aerial Vehicles," *Engineering*, vol. 27, pp. 242-253, 2023, https://doi.org/10.1016/j.eng.2022.10.018.