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Sensor Fusion and Conflict Resolution Strategies for Safe Multi-UAV Operations: A Comprehensive Review

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Abstract: The widespread adoption of unmanned aerial vehicle (UAV) across diverse sectors has increased the risk of collisions and heightened the urgency for robust collision avoidance mechanisms, especially in multi-UAV operations. This comprehensive review synthesizes recent advancements in conflict resolution and sensor fusion techniques for multi-UAV systems, highlighting their principles, applications, advantages, and limitations. An analysis of fifteen peer-reviewed papers published between 2020 and 2024 reveals the increasing adoption of decentralized architectures, model predictive control, geometric methods, and deep learning-integrated sensor fusion for dynamic obstacle detection and avoidance. These approaches enable UAVs to operate autonomously in uncertain and complex environments by improving conditional awareness and response times. Furthermore, the review highlights application domains such as precision agriculture, disaster response, and urban navigation. Eventually, limitations regarding sensor calibration, computational demands, and environmental variability are also discussed. Future research directions emphasize the need for hybrid decision frameworks, real-time processing, and AI-enhanced multi-sensor integration to support fully autonomous and cooperative UAV operations.

Keywords: Collision Avoidance, Conflict Resolution, Sensor Fusion, Multi-UAV Systems, Deep Learning, Distributed Architectures.

I. Introduction

Overview

The Unmanned Aircraft Systems (UAS) is anticipated to expand significantly worldwide for commercial and civil applications. According to the Single European Sky Air Traffic Management Research (SESAR), the European drone market will surpass 10 billion yearly by 2035 and 15 billion by 2050. Moreover, small UAS and very low-level airspace operations would provide the most incredible market value based on the characteristics of the missions and application fields. This expanding tendency will accompany a rise in traffic congestion and additional safety, reliability, and efficiency-related problems. Therefore, developing and deploying conflict management systems are prerequisites for UAS integration in civil airspace. Specifically, the National Aeronautics and Space Administration (NASA) in the United States (US) intends to develop a UAS Traffic Management (UTM) system that will let multiple UAS fly at low altitudes alongside other airspace users.

According to the Federal Aviation Administration (FAA), there will be 2.4 million small hobbyist drones in the US by 2022, and the incidence of drone accidents is sharply rising along with the popularity and deployment of Unmanned Aerial Vehicles (UAVs) for consumer applications. The FAA obtains over 100 monthly complaints of illegal and possibly dangerous UAV activity from pilots, residents, and law enforcement. These kinds of accidents highlight the necessity for drone pilot education and training programs, as well as tighter regulations for offenders. FAA also highlights the significance of a collision-free route creation and navigation system for UAVs. It is just as essential to guarantee safe and risk-free UAV flying while using it inside. As a result, keeping UAVs stable in flight is becoming a significant priority means that the UAVs can identify and avoid stationary and relocating objects. Examples of static impediments include buildings and trees, whereas dynamic obstacles include birds.

One of the challenges is how to safely integrate drones into the airspace structure with other aircraft in an urban area. Technical, operational, and regulatory issues are involved. A few years ago, the European Union started an endeavor to adopt more airspace regulations. The European Commission modified the UTM concept for Europe, added a framework of services and capabilities, and termed the outcome U-space. Since then, the SESAR Joint Undertaking (SESAR JU) of the European Commission has funded various European research projects. Some research projects concentrate on techniques and regulations that let drones fly in crowded areas without threatening other airspace users. For example, this includes U-space Separation in Europe (USEPE) projects, which investigate management and safe separation technology. The project uses geo-vectoring, high-speed corridors, and density-based management. NASA's project called UAS Integration in the National Airspace System (NAS) intends to create collision avoidance technology. Note that flight safety concerns aviation authorities like European Union Aviation Safety Agency (EASA) in Europe.

The Growing Need for Collision Avoidance Systems

The increasing use of Unmanned Aerial Vehicles (UAVs) in various applications has raised concerns about safety and efficiency, necessitating advanced collision avoidance systems [1]. To address this, researchers have proposed distributed conflict resolution algorithms using sensor fusion [1], sensor fusion-based collision avoidance systems using deep learning [4] and model predictive

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control [3],[9]. Decentralized architectures have also been explored for conflict resolution [4] and multi-UAV collision avoidance [6]. Furthermore, studies have investigated the use of geometric calculations, deep reinforcement learning [11], and sensor fusion techniques [12] for enhanced collision avoidance capabilities. Additionally, researchers have developed decentralized model predictive control algorithms [2].

Background

UAVs are increasingly used in applications such as package delivery, aerial surveillance, and search and rescue operations. However, their growing numbers have increased the risk of collisions, emphasizing the need for efficient collision avoidance systems. Various sensors, including GPS, lidar, radar, and cameras, are used to detect obstacles and avoid collisions.

Recent research has proposed solutions including:

Conflict Resolution Techniques

Research has shown that distributed conflict resolution algorithms using sensor fusion can enhance situational awareness and reduce collision risk [1].

Decentralized conflict resolution algorithms using velocity obstacles have also been developed to ensure safe UAV separation.

Sensor Fusion Techniques

Sensor fusion techniques combine data from various sensors to enhance situational awareness and improve detection accuracy. Studies have demonstrated the effectiveness of sensor fusion-based collision avoidance systems using deep learning [8],[9]. Distributed sensor fusion algorithms have also been proposed for multi-UAV collision avoidance [6].

Model Predictive Control

Model predictive control (MPC) has been used to optimize UAV trajectories and avoid collisions. Research has integrated MPC algorithms with sensor fusion techniques to enhance collision avoidance capabilities [2].

Deep Learning

Deep learning techniques have been applied to sensor fusion and conflict resolution to enhance UAV collision avoidance capabilities. Studies have demonstrated the effectiveness of deep reinforcement learning in developing multi-sensor fusion algorithms [11].

Geometric Calculations

Geometric calculations have been used to enhance collision avoidance capabilities. Research has proposed algorithms using sensor fusion and geometric calculations to detect potential collisions [11].

Decentralized Architectures

Decentralized architectures have been proposed to enhance scalability and efficiency in multi-UAV systems. Research has developed decentralized model predictive control algorithms for conflict resolution [11]

Multi-UAV Collision Avoidance

Multi-UAV collision avoidance systems have been developed using decentralized sensor fusion and model predictive control. Studies have demonstrated the effectiveness of these systems in enhancing situational awareness and detection accuracy [6].

These developments are shaping the future of autonomous UAV operations and underpin the direction of this review.

The importance of collision avoidance in UAV operations.

Critical Safety Requirement: Collision avoidance is a critical safety requirement in UAV operations to prevent accidents and ensure safe separation of UAVs from other air traffic, obstacles, and people on the ground[1]. The Federal Aviation Administration (FAA) emphasizes the importance of collision avoidance systems in UAV operations (FAA, 2020).

Prevention of Fatalities and Damage

Effective collision avoidance systems can prevent fatalities and damage to property, thereby reducing the risk of harm to humans and the environment[14]. The economic costs of UAV accidents can be significant, emphasizing the importance of collision avoidance systems.

Enhanced Situational Awareness

Collision avoidance systems provide enhanced situational awareness to UAV operators, enabling them to make informed decisions and respond promptly to potential collisions[3].

- UAV operators require real-time information about their surroundings to ensure safe operation.

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- Collision avoidance systems provide situational awareness, enabling UAV operators to detect potential collision
- Effective collision avoidance systems enhance UAV operator decision-making and response times

Research Gap

Despite recent advances, there remains a research gap in conflict resolution and sensor fusion techniques for UAV collision avoidance. Future research should focus on integrating AI and machine learning, developing efficient sensor fusion algorithms, and exploring decentralized architectures.

Objectives

This review aims to provide a comprehensive overview of conflict resolution and sensor fusion techniques for UAV collision avoidance

II. Methodology

This section outlines the systematic methodology employed to gather, screen, and analyze the existing body of knowledge on sensor fusion and conflict resolution strategies for UAV collision avoidance. The goal was to identify major trends, key contributions, strengths, and limitations of the reviewed techniques, as well as to define the current research gap and future opportunities.

Research Design

To ensure transparency, the study adopts a Systematic Literature Review (SLR) framework, replicability, and rigor in analyzing published research. The review focuses on recent advancements (2020–2024) in the areas of multi-UAV collision avoidance, sensor fusion, and conflict resolution strategies. This methodology allows the authors to synthesize a wide spectrum of approaches and technologies by categorizing them based on technique, architecture, sensor type, and application.

Search Strategy

Relevant articles were retrieved from reputable databases including IEEE Xplore, SpringerLink, ScienceDirect and Google Scholar. Keywords used included: This review uses a systematic literature review approach to identify relevant studies. The search strategy includes keywords and explains in detail how the method works and its key principle.

Inclusion Criteria:

- Peer-reviewed articles (2020–2024)
- Focus on UAV collision avoidance, sensor fusion, or conflict resolution
- Experimental, simulated, or algorithmic studies

Selection and Analysis

From an initial pool of uu80 publications, **15 studies** were selected after abstract and full-text screening. Each paper was evaluated for:

- Sensor and fusion architecture used
- Conflict resolution technique
- Evaluation environment and metrics
- Applicability to multi-UAV scenarios

These studies were categorized into thematic areas, forming the basis for discussion in Chapter 3.

Limitations

The review is limited to English-language publications and does not include industrial patents or commercial solutions. Performance comparisons are based on reported data, which may not always be directly comparable.

III. Analysis and Discussion of Conflict Resolution and Sensor Fusion Techniques

UAV collision avoidance," "sensor fusion," "conflict resolution Unmanned vehicles typically contain a variety of sensors on board that can be utilized for autonomous decision-making and situational awareness during operation [16]. In general, control can be either autonomous, relying on feedback from a mounted camera and other sensors identifying the impending obstacles, or manual, based on, for example, live video received from a camera mounted on a vehicle (remote control) [17], [18]. The need for unmanned vehicles is growing quickly, and developing effective path planning for them in dynamic environments continues to be a significant challenge to address [19]

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Unmanned aerial vehicles (UAVs) can reach hazardous and hard-to-reach places without endangering people, unlike cars that use collision avoidance. Therefore, it is necessary to do basic research in order to create UAVs that are fully autonomous and capable of flying without running into other objects [20].

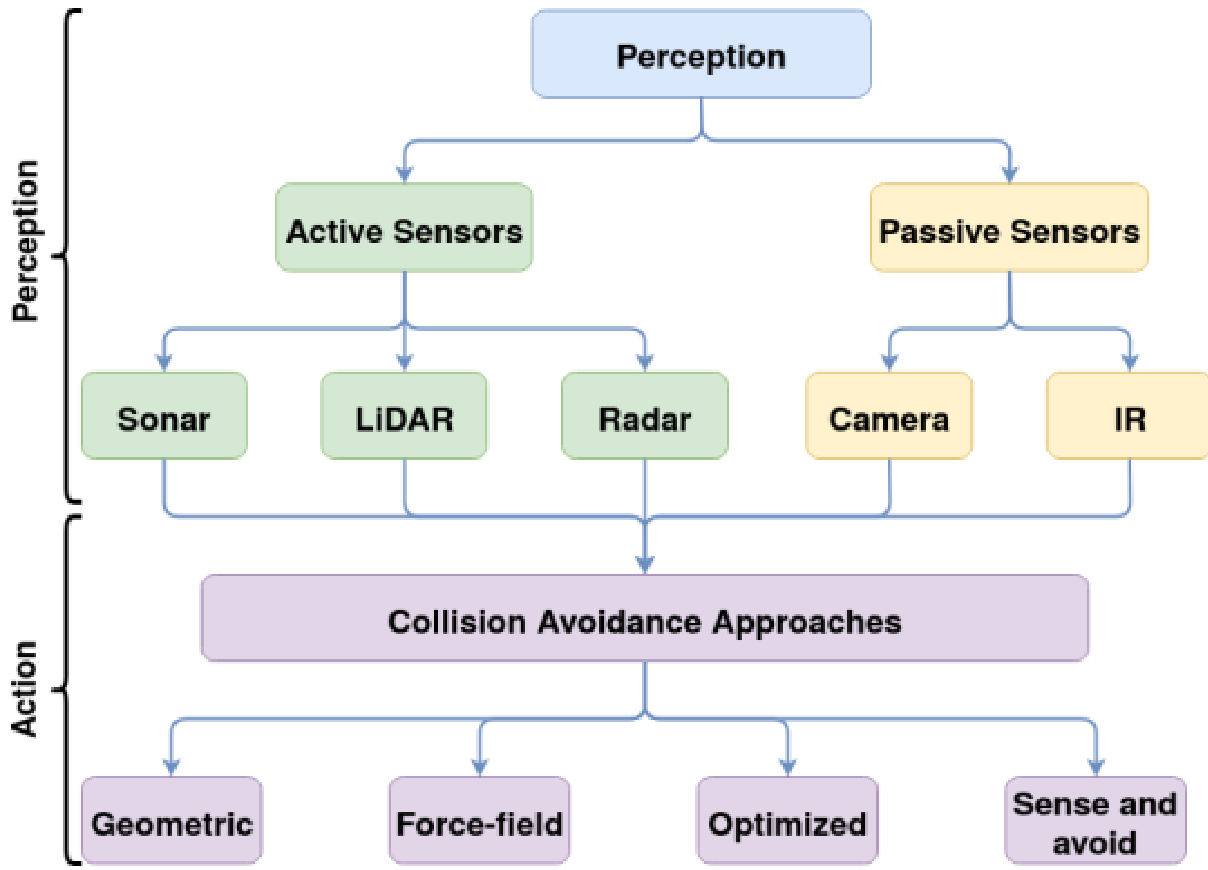

Figure 1: Collision Avoidance System Generalized Modules

This paper provides a comprehensive overview of the major trends and significant research in collision avoidance for autonomous systems. It organizes and encapsulates key concepts and methods into various categories to highlight distinct approaches. The classification, illustrated in Figure 1, is divided into two main categories: perception and action. This order, from top to bottom, reflects the process in collision avoidance, where perception is necessary before taking action.

Obstacle detection is the initial phase in any collision avoidance system, involving the use of sensors to perceive the environment and identify obstacles. Sensors are broadly classified as active or passive based on their operating principles (detailed in Section 2). Active sensors emit light or waves and detect the reflected signal, while passive sensors rely on detecting energy reflected from an object, such as sunlight.

Collision avoidance systems can be as simple as alerting the operator [21] or as complex as autonomously regulating the system entirely or in part to prevent a collision.

Actuators in collision avoidance systems function by either braking or steering the vehicle away from an obstacle. Early research focused on ground vehicles on advanced highways, which laid the groundwork for developments in intelligent aerial and surface vehicles[22],[[23]. One notable classification approach differentiates collision avoidance into global and local path planning. Global path planning generates optimal routes by considering the entire environment and responding to changes, while local path planning, also known as collision avoidance, addresses immediate environmental changes by performing maneuvers to avoid obstacles and return to the original path [24].

Conflict Resolution Strategies (VO, MPC, Deep RL, etc.)

Conflict resolution and sensor fusion techniques are indispensable for advancing UAV collision avoidance systems. The synergy between these technologies enhances operational safety, scalability, and efficiency. By addressing current challenges and exploring future directions, the UAV industry can achieve a transformative leap in autonomy and reliability. This progress will pave the way for broader adoption across diverse sectors, reinforcing the vital role of UAVs in modern society.

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Sensor Fusion Techniques (centralized, decentralized, learning-based)

Fusion Paradigm	**Example(s)**	**Key Characteristics**
Centralized	Standard EKF master filter (Sensors hybrid architecture)	All raw data fused centrally; simple but bandwidth-intensive and single-point vulnerable
Decentralized	Touretsky neural network, CI-based extended object tracking	Data fused locally; robust to faults, scalable, reduced communication
Learning-based / Hybrid	End-to-end neural fusion; adaptive Kalman + semantic VLM	Automatically learn fusion weights or adapt filter parameters; robust to noise/outliers

Perception Systems (passive vs active sensors)

Perception is the initial phase of any collision avoidance system, requiring the drone to be capable of observing its environment through a perception unit [25] composed of one or more sensors. For remote sensing, imaging sensors of varying resolutions are critical. The choice of sensors varies based on specific requirements and can include LiDAR, visual cameras, thermal or infrared cameras, and optomechanical or solid-state devices [26],[27]. These sensors are generally classified by their spectral sensitivity and the parts of the electromagnetic spectrum they use, as illustrated in Figure 3.[28].

To detect obstacles, various types of sensors are utilized, which can be broadly classified into two main categories:

- Passive Sensors
- Active Sensors

Passive Sensors

Passive sensors detect energy emitted by objects or the environment being observed. Common examples include optical or visual cameras, thermal or infrared (IR) cameras, and spectrometers [29],[30]. These sensors operate across various wavelengths, such as visible light, different infrared ranges (short-wave, near-wave, mid-wave, and long-wave), and the ultraviolet (UV) band [31].

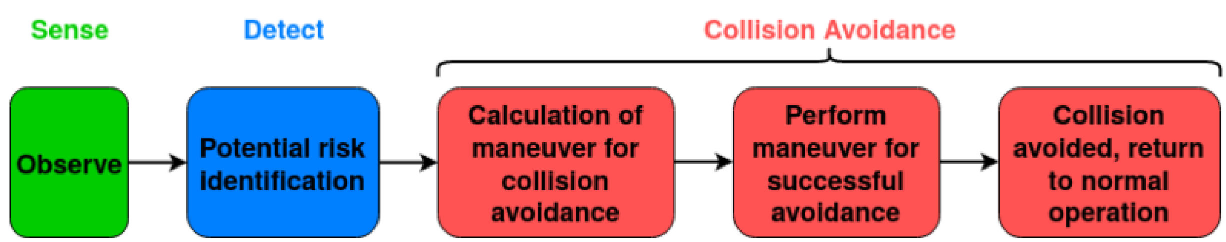

FIGURE 3: General Process for Collision Avoidance

Active Sensors

Active sensors operate by emitting a signal, such as an electrical, acoustic, or light wave which reflects off objects and is detected by a receiver. This class of sensors includes LiDAR [49], radar [60], sonar, ultrasonic sensors [32][33], and active infrared sensors [34][35]. They are well-suited for UAV applications due to their fast response times, ability to function in varied weather conditions, and low computational demands. These sensors can provide precise data on obstacle distance and angles, enabling real-time detection. For example, millimeter-wave (MMW) radar systems determine the distance between objects by analyzing radar echoes [36]. While radar is highly reliable in weather-affected environments, it may be expensive or too heavy for smaller UAV platforms.

Collision Avoidance Architectures (single UAV vs multi-UAV, swarm)

Collision avoidance systems can be as simple as alerting the operator [19] or as complex as autonomously regulating the system entirely or in part to prevent a collision.

Actuators in collision avoidance systems function by either braking or steering the vehicle away from an obstacle. Early research focused on ground vehicles on advanced highways, which laid the groundwork for developments in intelligent aerial and surface vehicles [20], [[21]. One notable classification approach differentiates collision avoidance into global and local path planning. Global path planning generates optimal routes by considering the entire environment and responding to changes, while local path planning, also known as collision avoidance, addresses immediate environmental changes by performing maneuvers to avoid obstacles and return to the original path [22].

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A Collision Avoidance System (CAS) consists of three main components: sensing, detecting, and avoiding collisions, as illustrated in Fig. 3. The process begins with the sensing phase, where the system monitors its environment. When an obstacle enters the detection range, the system evaluates the potential risk. The collision avoidance module then calculates the required deviation from the current path to prevent a collision. Once these calculations are complete, the system executes the necessary maneuver to avoid the obstacle.

Real-World Applications

The real-world applications of sensor fusion techniques, as described above, primarily focus on enhancing the capabilities of UAVs (Unmanned Aerial Vehicles) for collision avoidance and obstacle detection. Here are some key applications highlighted in this review:

Obstacle Detection and Avoidance

Sensor fusion techniques are crucial for enabling UAVs to detect and avoid obstacles in real-time. By combining data from various sensors, such as LiDAR, cameras, and ultrasonic sensors, UAVs can create a comprehensive understanding of their environment. This is particularly important in complex and dynamic settings, where obstacles may not be easily distinguishable by a single sensor type. For instance, LiDAR can provide precise distance measurements, while cameras can offer visual context to identify the nature of obstacles, such as distinguishing between a tree and a building [7].

Enhanced Situational Awareness

UAVs equipped with sensor fusion capabilities can achieve a higher level of situational awareness. By integrating data from multiple sources, UAVs can better understand their surroundings, including the presence of other vehicles, pedestrians, and environmental features. This enhanced awareness is critical for safe navigation, especially in urban environments where obstacles are abundant and varied

Dynamic Path Planning

Sensor fusion allows UAVs to adapt their flight paths in real-time based on the data received from their sensors. For example, if a UAV detects an unexpected obstacle using its sensors, it can quickly calculate a new route to avoid a collision.

This dynamic path planning is essential for applications such as delivery services, where UAVs must navigate through changing environments.

Search and Rescue Operations

In search and rescue missions, UAVs can utilize sensor fusion to locate missing persons or assess disaster-stricken areas. By fusing data from thermal cameras, visual cameras, and LiDAR, UAVs can identify heat signatures or structural damages, providing critical information to rescue teams. This capability enhances the effectiveness and efficiency of search operations.

Agricultural Monitoring

In agriculture, UAVs equipped with sensor fusion techniques can monitor crop health and assess field conditions. By combining data from multispectral cameras and LiDAR, UAVs can analyze vegetation indices and create detailed maps of crop health, enabling farmers to make informed decisions about irrigation, fertilization, and pest control.

Autonomous Vehicles

The principles of sensor fusion used in UAVs are also applicable to autonomous ground vehicles. By integrating data from various sensors, such as radar, cameras, and ultrasonic sensors, these vehicles can navigate safely in complex environments, avoiding obstacles and making real-time driving decisions.

Advantages and Limitations

Advantages of Sensor Fusion Techniques in Collision Avoidance

Improved Accuracy: By combining data from multiple sensors, sensor fusion enhances the accuracy of obstacle detection and environmental perception. This leads to more reliable identification of obstacles and potential collision threats.

Robustness to Environmental Conditions: Sensor fusion allows UAVs to operate effectively in various environmental conditions. For instance, active sensors like LiDAR and ultrasonic sensors are less affected by lighting conditions compared to passive sensors like cameras, making the system more reliable in adverse weather or low-light situations.

Enhanced Situational Awareness: Integrating data from different sensors provides a comprehensive view of the surroundings, improving the UAV's situational awareness. This is crucial for navigating complex environments with dynamic obstacles.

Real-time Processing: Sensor fusion techniques enable real-time data processing, allowing UAVs to react quickly to changes in their environment. This is essential for timely collision avoidance maneuvers.

Reduction of False Positives: By fusing data from multiple sources, the likelihood of false positives in obstacle detection can be reduced. This minimizes the chances of unnecessary evasive actions, which can disrupt flight paths.

Adaptability: Sensor fusion systems can adapt to different operational requirements and environments. This flexibility allows for the integration of various sensor types based on specific mission needs.

Increased Safety: The combination of multiple sensors enhances the overall safety of UAV operations. By providing a more reliable detection and avoidance system, the risk of collisions is significantly reduced.

Support for Complex Algorithms: Sensor fusion facilitates the implementation of advanced algorithms for collision avoidance, such as machine learning and artificial intelligence, which can further enhance decision-making processes.

Cost-Effectiveness: While implementing multiple sensors may seem costly, the overall reduction in collision incidents and the associated costs can make sensor fusion a cost-effective solution in the long run.

Limitations

Despite significant advancements, challenges persist, including sensor calibration, environmental variability, latency issues, and the computational demands of real-time processing. These limitations underscore the need for further research into adaptive algorithms and hardware optimization.

Future Direction

Future research should focus on developing adaptive, real-time collision avoidance algorithms that can switch between reactive and deliberative modes. Enhancing sensor fusion by integrating LiDAR, radar, and cameras, along with AI and machine learning, will improve obstacle prediction and path planning. To support small UAVs, efforts must also improve computational efficiency. For multi-UAV systems, scalable swarm coordination strategies are needed. Robustness in challenging environments and the use of hybrid approaches combining geometric and optimization methods will further strengthen UAV autonomy and safety.

Key Findings and Contributions

Conflict Resolution Techniques: Distributed algorithms and decentralized architectures play a pivotal role in ensuring UAV safety and operational scalability. Techniques such as velocity obstacles, model predictive control (MPC), and geometric methods effectively address multi-agent coordination in dynamic environments.

Sensor Fusion Approaches: Sensor fusion enhances situational awareness and detection accuracy by integrating data from diverse sources, such as cameras, LiDAR, radar, and infrared sensors. This fusion ensures a comprehensive understanding of the operational environment, significantly reducing false positives and improving collision prediction.

Role of Deep Learning: The integration of deep learning and reinforcement learning in sensor fusion systems provides advanced predictive capabilities, enabling UAVs to adapt to complex, rapidly changing scenarios. These methods enhance obstacle detection, trajectory planning, and system robustness.

Scalability through Decentralization: Decentralized systems improve the scalability of collision avoidance systems by distributing computational and decision-making tasks among UAVs. This approach is critical for swarm-based operations, such as search and rescue or large-scale surveillance.

IV. Conclusion

The rapid growth of UAV applications across various domains, including commercial, civil, and emergency services, necessitates the development of robust collision avoidance systems (CAS). This review has comprehensively explored the landscape of conflict resolution and sensor fusion techniques for multi-UAV systems, offering insights into their principles, methodologies, advantages, and limitations.

References

1. H. Liu et al., “A survey of sensors based autonomous unmanned aerial vehicle (UAV) localization techniques,” Complex & Intelligent Systems, vol. 11, Art. no. 371, Jul. 2025.
2. M. Goarin, G. Li, A. Saviolo, and G. Loianno, “Decentralized nonlinear model predictive control for safe collision avoidance in quadrotor teams with limited detection range,” arXiv preprint arXiv:2409.17379, Sept. 2024.
3. H. Liu, H. Liu, X. Li, and Y. Liu, “A survey of sensors-based autonomous unmanned aerial vehicle (UAV) localization techniques,” Complex & Intelligent Systems, vol. 11, Art. no. 371, Jul. 2025. doi: 10.1007/s40747-025-01961-2
4. X. Wang et al., “Learning based UAV path planning for data collection with integrated collision avoidance,” arXiv preprint, Dec. 2023.
5. J. Yan, J. Feng, and F. Pan, “A distributed task allocation method for multi UAV systems in communication constrained environments,” Drones, vol. 8, Art. no. 342, Jul. 2024.
6. C. Li et al., “Advances and emerging trends in UAV sensor data fusion technology,” 2025. [Online].

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VIII, August 2025

7. D. Debnath et al., "A review of UAV path planning algorithms and obstacle avoidance methods for remote sensing applications," Remote Sensing, vol. 16, Art. no. 4019, Oct. 2024.
8. A. James et al., "Sensor fusion for autonomous indoor UAV navigation in confined spaces," in Proc. IEEE ICST, 2023.
9. K. Yue, "Multi-sensor data fusion for autonomous flight of unmanned aerial vehicles in complex flight environments," Drone Systems and Applications, vol. 12, pp. 1–12, 2024. doi: 10.1139/dsa-2024-0005
10. D. Wanner, H. A. Hashim, S. Srivastava, and A. Steinhauer, "UAV avionics safety, certification, accidents, redundancy, integrity, and reliability: A comprehensive review and future trends," Drone Systems and Applications, vol. 12, pp. 1–23, Jun. 2024, doi: 10.1139/dsa-2023-0091.
11. N. Alhousani, M. Saveriano, I. Sevinc, T. Abdulkuddus, H. Kose, and F. J. Abu-Dakka, "Geometric Reinforcement Learning for Robotic Manipulation," IEEE Access, vol. 11, pp. 111492–111505, 2023, doi: 10.1109/ACCESS.2023.3322654.
12. Yeong, D. J., Velasco-Hernandez, G., Barry, J., & Walsh, J. (2021). Sensor and Sensor Fusion Technology in Autonomous Vehicles: A Review. Sensors, 21(6), 2140. https://doi.org/10.3390/s21062140
13. M. Harun et al., "Recent developments and future prospects in collision avoidance control for unmanned aerial vehicles (UAVs): A review," Int. J. Robotics and Control Systems, vol. 4, no. 3, pp. 1207–1242, Aug. 2024.
14. S. Du et al., "Safety risk modelling and assessment of civil unmanned aircraft system operations: A comprehensive review," Drones, vol. 8, no. 8, 2024.
15. S. A. et al., "Resilient multi-sensor UAV navigation with a hybrid federated fusion architecture," Sensors, vol. 24, no. 3, Art. no. 981, Feb. 2024.
16. W. Zhang, G. Zelinsky, and D. Samaras, "Real-time accurate object detection using multiple resolutions," in Proc. IEEE Int. Conf. Computer Vision, Oct. 2007, pp. 1–8.
17. S. N. Shinde and S. Chorage, "Unmanned ground vehicle," Int. J. Adv. Eng. Manage. Sci., vol. 2, no. 10, 2016.
18. H. Chao, Y. Cao, and Y. Chen, "Autopilots for small unmanned aerial vehicles: A survey," Int. J. Control, Autom. Syst., vol. 8, no. 1, pp. 36–44, Feb. 2010. [Online]. Available: https://doi.org/10.1007/s12555-010-0105-z
19. C. Zhuge, Y. Cai, and Z. Tang, "A novel dynamic obstacle avoidance algorithm based on collision time histogram," Chin. J. Electron., vol. 26, no. 3, pp. 522–529, 2017.
20. D. H. Shim, H. Chung, H. J. Kim, and S. Sastry, "Autonomous exploration in unknown urban environments for unmanned aerial vehicles," in Proc. AIAA GNC Conf., 2005.
21. PlaneCrashInfo.com, "Accident statistics." [Online]. Available: http://www.planecrashinfo.com/cause.htm
22. D. H. Shim, H. Chung, H. J. Kim, and S. Sastry, "Autonomous exploration in unknown urban environments for unmanned aerial vehicles," in Proc. AIAA GNC Conf., 2005.
23. R. J. Kiefer, D. K. Grimm, B. B. Litkouhi, and V. Sadekar, "Collision avoidance system," U.S. Patent 7,245,231, Jul. 17, 2007.
24. G. Ladd and G. Bland, "Non-military applications for small UAS platforms," in AIAA Infotech@Aerospace Conf. and AIAA Unmanned... Unlimited Conf., 2009, p. 2046.
25. L. He, P. Bai, X. Liang, J. Zhang, and W. Wang, "Feedback formation control of UAV swarm with multiple implicit leaders," Aerosp. Sci. Technol., vol. 72, pp. 327–334, 2018. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1270963816309816
26. S. S. Esfahlani, "Mixed reality and remote sensing application of unmanned aerial vehicle in fire and smoke detection," J. Ind. Inf. Integr., 2019. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S2452414X18300773
27. H. Shakhatreh et al., "Unmanned Aerial Vehicles (UAVs): A Survey on Civil Applications and Key Research Challenges," IEEE Access, vol. 7, pp. 48572–48634, 2019.
28. C. A. Wargo, G. C. Church, J. Glaneueski, and M. Strout, "Unmanned aircraft systems (UAS) research and future analysis," in Proc. IEEE Aerosp. Conf., 2014, pp. 1–16.
29. Z. Xu, Y. Zhang, Y. Zhang, and F. Gao, "Vision-aided UAV navigation using gradient-based B-spline trajectory optimization," arXiv preprint arXiv:2209.07003, 2022. [Online]. Available: https://arxiv.org/abs/2209.07003
30. X. Wang, V. Yadav, and S. N. Balakrishnan, "Cooperative UAV formation flying with obstacle/collision avoidance," IEEE Trans. Control Syst. Technol., vol. 15, no. 4, pp. 672–679, Jul. 2007.
31. G. Recchia, G. Fasano, D. Accardo, A. Moccia, and L. Paparone, "An optical flow based electro-optical see-and-avoid system for UAVs," in Proc. IEEE Aerosp. Conf., Mar. 2007, pp. 1–9.
32. F. Kóta, T. Zsedrovits, and Z. Nagy, "Sense-and-avoid system development on an FPGA," in Proc. Int. Conf. Unmanned Aircraft Syst. (ICUAS), Jun. 2019, pp. 575–579.
33. A. McFadyen, A. Durand-Petiteville, and L. Mejias, "Decision strategies for automated visual collision avoidance," in Proc. Int. Conf. Unmanned Aircraft Syst. (ICUAS), 2014, pp. 715–725.
34. R. Beard and J. Saunders, "Reactive vision based obstacle avoidance with camera field of view constraints," in AIAA Guidance, Navigation and Control Conf., 2008, p. 7250.
35. H.-J. Cho and M.-T. Tseng, "A support vector machine approach to CMOS-based radar signal processing for vehicle classification and speed estimation," Math. Comput. Model., vol. 58, no. 1, pp. 438–448, 2013. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0895717712003020