Collision Avoidance Systems for Internet of drones: An overview

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***Abstract*—Internet of Drones (IoD) paradigm offers a wide range of applications mainly targeting the military and civilian environments. Some of those applications include transportation, agriculture based systems, entertainment, weather monitoring, healthcare systems and road hazards monitoring. However, once an area is highly congested by various number of drones, dynamic or statics obstacles can hinder the overall performance of drones. In order to avoid those obstacles, one of the proposed solution is to apply collision avoidance techniques while the drones are on duty. In this paper, we present an brief survey of collision avoidance systems for the internet of drones. We have reviewed the current literature review ranging from the year 2010 to 2021. This work has taken into consideration two main frequently used database in the academia: Xplore for IEEE and ScienceDirect for Elsevier. After article selection, only 15 articles were retained and discussed. A detailed discussion and analysis of selected articles was made while most of the techniques used in collision avoidance systems include video based systems and swarm based intelligence approaches. Finally, this paper provides concluding remarks and future research orientation that will mainly focus on AI based systems for collision avoidance systems.**

***Index Terms*—Internet of Things, Unmanned Aerial vehicles, Internet of Drones, Prediction, Collision avoidance.**

I. Introduction

From definition, an unmanned aerial vehicle (UAV) commonly known as a drone, is an aircraft without a human pilot on board [18]. UAVs are a component of an unmanned aircraft system (UAS), which include additionally a ground-based controller and a system of communications with the UAV. On the other hands, Internet of Drones (IoDs) consists of a number of drones that are able to communicate and share information in the perspective of monitoring or reporting an event that have occurred in a certain place or region. Drones are also defined as aircraft based devices that are able to fly or operate with passengers [6]. The Internet of drones is applicable in a multitude of areas mostly in the civilian environment. Those areas of applications include traffic monitoring, packets or good delivery, accident detection systems, agriculture inspection and monitoring system, emergency and rescue based systems. Drones are also widely used in the military domain with a number of applications and event already documented in the literature.

For the last decades, there is a growing usage of drones for consumer based applications such as entertainment based system or delivery based systems. There are number of drones

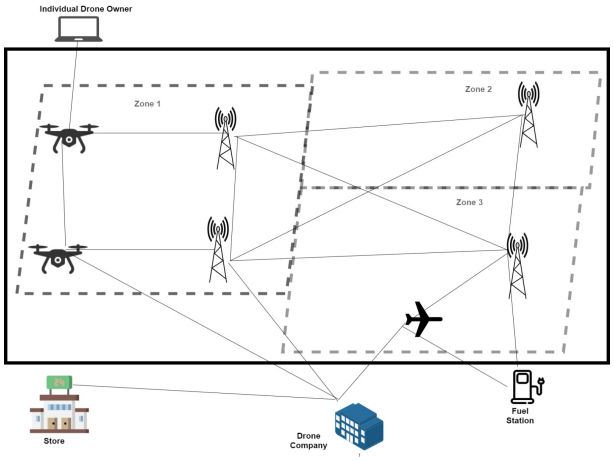

Fig. 1: Internet of drones architecture

that are used in the civilian domain and one of the most popular is the the quadrotor DJI Phantom 4 pro. DJI 4 Pro has become very popular due to its characteristics such as price affordability, small size, easy and simple design and ability of hovering in place [14]. Accordingly, the number of accidents for drones have been widely reported.

The obstacles can be divided in two main categories: static obstacles and dynamics obstacles. For the first category of static obstacles, these are fixed entities that are located in known places. These can be building, electric equipment or any other equipment. The second category of obstacles are dynamics obstacles and consists of objects that can suddenly appear on the pathway of a drone and their location can change. Either dynamic or static, these obstacles have to be detected during the mission of a drone. Collision avoidance system are assumed to have an efficient detection mechanism that is able to detect both the speed and the direction of dynamic obstacles while having a complete knowledge of static obstacles.

In this paper we present an brief survey of collision avoidance systems for the internet of drones and our contribution is three folds:

- We first describe the existing elements that affect the performance of internet of drones mostly the collision avoidance system.
- We latter describe the procedure that was used to choose

and select the articles that were considered in this work.
- And lastly, we provide a thorough analysis through a systematic review of selected articles by emphasizing on the used techniques,research goals, used techniques along with findings, followed by the future research directions

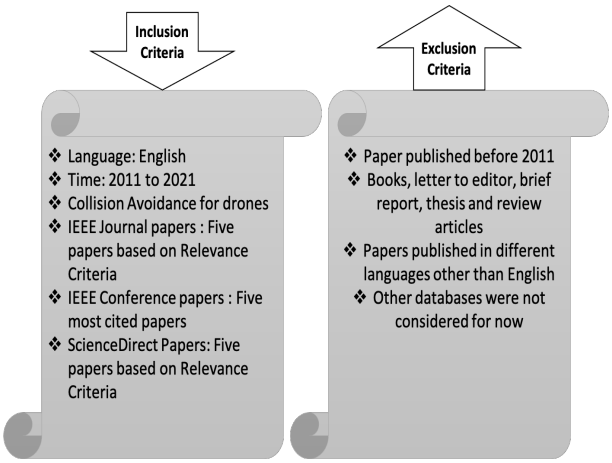

Fig. 2: Article Selection Process

II. Literature Review

In the section, we present mainly the procedure that was used for articles selection. In addition, we discussed a number of articles on existing work that attempted to provide surveys on collision avoidance based techniques on Internet of drones.

Among the existing work, there are a number of references that surveyed on collision avoidance systems.

In [13], Guan et al. discussed a survey of safety separation management and collision avoidance approaches of civil UAS operating in the integrated national airspace system. In their work, the authors tried to make a review of the UAS separation management and key technologies used in collision avoidance systems within the integrated airspace. Their work mainly focused on the current situation of UAS Traffic Management (UTM), safety separation standards, detection system, collision risk prediction, collision avoidance, safety risk assessment, etc., as well as an analysis of the bottlenecks that the current researches encountered and their development trends.

In [7], Huang et al. presented an overview of various approaches for multi-UAV collision avoidance under several classifications based on algorithm used, frameworks designed and their main features.

Tahir et al. [12] made an analysis of the core characteristics of swarming drones and the public awareness levels with respect to these swarms. This study showed that the swarms of drones are a fundamental part on future agenda. Thus emphasizing the need of strong and robust avoidance systems.

Aggarwal et al. [1] paper focused on path planning for unmanned aerial vehicles (UAVs) in order to find an optimal path between source and destination. The main objective of path planning techniques is not only to find an optimal and shortest path but also to insure the collision-free environment to the UAVs. It is important to have path planning techniques to calculate a safe path in the shortest possible time to the final destination.

Based on the aforementioned literature, the overall research on effective collision avoidance systems is still in early states, thus the need to provide a more comprehensive study on the topic.

In this work, various databases were extracted for to acheive accurate review. Those database are mainy Xplore for IEEE based articles and Sciencedirect for Elsevier based articles. Other librairies including Springer, ACM, Google Scholar, Wiley digital library will be used for the future work of this articles. This is mainly due ot the number of page limitation. In order to select the articles, the following keywords including “internet of drones”, “unmanned aerial vehicles”, “collision avoidance system”. The selection procedure is illustrated in Fig. 2

In this subsection, the outcome of 45 research articles was taken into consideration. As shown in Fig. 2 those research articles were chosen or taken into consideration based on inclusion and exclusion criteria. Concerning the exclusion criteria, only qualified articles were chosen. However book chapters and from book, thesis, and other summary reports were excluded. Other available articles including Journal editorials, newsletter or papers which were not in English were excluded. After reviewing all collected articles, only 15 papers were retained for in-depth analysis and study.

III. Discussions

In this section, we provide the discussion of the articles that we surveyed. As shown in the table, we mainly focus on the topics which was covered, the research goals that were intended to handle, the methodology that was used and the findings Due to page limitation, we have only discussed 15 articles and the we intend to provide more in future work. Based on the discussed paper, the avoidance systems are discussed in the following main directions

1) Video based Systems: There are number of works that focused on providing collision avoidance systems using video based solutions. In these work [15] and [10] attempted to generate to automatically generate drone trajectories such as the imagery acquired during the flight, thus the image will will later produce a high 3D model that can be used to for collision avoidance systems. Their main techniques were mainly divided in the following steps: they first provided an estimation of the scene geometry to plan camera trajectories. Later on, they used the trajectory to cover the scene as thoroughly as possible. In addition, they made an algorithm that make observations of scene geometry from a diverse set of viewing angles. The combination of all those provided algorithms allowed them to establish collision systems to avoid obstacles.

2) Swarm Based Intelligence Systems: There are a number of solutions also relied on swarm based intelligence systems. Among them , the authors in [17] proposed a solution to dynamically handle the duality of control. Their proposed scheme focused on adapting the thin-plate splines algorithms

Tab. I: Discussion of selected articles

Study	Topic	Research Goals	Methodology	Findings
[17]	UAV and Swarm intelligence	Dynamically handle this duality of control	formation-collision co-awareness by adapting the thin-plate splines algorithm to minimize deformation of the swarm's formation while avoiding obstacles	Simulation results show that the proposed methodology maintains the desired formation very closely in the presence of obstacles, while the response time and overall energy efficiency of the swarm is significantly improved.
[15]	Obstacle avoidance	To present a real-time onboard approach for monocular depth prediction and obstacle avoidance with a lightweight probabilistic CNN (pCNN)	Predict every video frame depth map and the corresponding confidence. The estimated depth map is transformed into Ego Dynamic Space (EDS) by embedding both dynamic motion constraints of a drone and the confidence values into the spatial depth map	Extensive experimental results on public datasets demonstrate that their depth prediction method is 1.8X5.6X faster than the state-of-the-art methods and achieves better depth estimation accuracy.
[11]	Collision avoidance	Design of a positive potential function to take into account the movement of obstacles	A controller was designed with hierarchical objectives using a behavioral-based approach. A nullspace-based controller is adopted, whose main objective is to ensure that the collision avoidance is achieved, whereas other objectives are projected onto the null space.	****Stability of the entire closed-loop nonlinear system is demonstrated through Lyapunov's theory.A low-cost indoor framework with just one RGB-D sensor, which is a combination of a RGB (red-green-blue) camera with a depth sensor based on infrared light was used to estimate the positions of the UAV and obstacles.
[3]	Flying Swarm of drones	Flying Swarm of Drones Over circulant Digraph	Their method is fundamentally different than any known to date since it does not need sensors to avoid collisions between drones. In addition, the flight of drones does not have to be coordinated.	The authors presented a novel framework for collisionless flying of many drones without the need for collision-detecting sensors or flight synchronization. Their method presented an algorithm that was scalable to hundreds of drones and allows to fly all of them from a single ground station
[16]	Autonomous aerial vehicles	The paper provides a comprehensive review of collision avoidance strategies used for unmanned vehicles, with the main emphasis on unmanned aerial vehicles (UAV).	It is an in-depth survey of different collision avoidance techniques that are categorically explained along with a comparative analysis of the considered approaches w.r.t. different scenarios and technical aspects.	The paper provides a comprehensive review of collision avoidance strategies used for unmanned vehicles, with the main emphasis on unmanned aerial vehicles (UAV).
[4]	UAV and obstacles avoidance	To learn to navigate an Unmanned Aerial Vehicle (UAV) and avoid obstacles	****A drone samples naive trajectories and crashes into random objects. The drone was crashed 11,500 times to create one of the biggest UAV crash dataset. This dataset captures the different ways in which a UAV can crash. We use all this negative flying data in conjunction with positive data sampled from the same trajectories to learn a simple yet powerful policy for UAV navigation	This simple self-supervised model is quite effective in navigating the UAV even in extremely cluttered environments with dynamic obstacles including humans.
[5]	Unmanned Aircraft Systems (UAS)	To develop a system that can identify/detect a UAS, which will subsequently enable counter measures against UAS.	Identify a UAS through various methods including image processing and mechanical tracking.	***The proposed system will help keep the malicious or harmful UAS away from the restricted or residential areas.
[10]	Drones 3D Scanning	To automatically generate drone trajectories such that the imagery acquired during the flight will later produce a high fidelity3D model.	*****coarse estimate of the scene geometry to plan camera trajectories that: (1) cover the scene as thoroughly as possible; (2) encourage observations of scene geometry from a diverse set of viewing angles; (3) avoid obstacles; and (4) respect a user-specified flight time budget.	centroid technique improve outcome with defuzzification
[9]	Path planning	To diagnosis diabetic a Fuzzy Expert System used to investigate the diabetes data.it is set off fuzzy membership functions and rules	The fuzzy mechanism consists of fuzzy inference, Collection of rules. also use fuzzy T-norm and T-Conorm operators. To convert fuzzy values into crisp set Defuzzification has been used.	The developed model obtain much accurate results than previous models.

[8]	Collision avoidance	To diagnosis diabetic a Fuzzy Expert System used to investigate the diabetes data.it is set off fuzzy membership functions and rules	The fuzzy mechanism consists of fuzzy inference, Collection of rules. also use fuzzy T-norm and T-Conorm operators. To convert fuzzy values into crisp set Defuzzification has been used.	The developed model obtain much accurate results than previous models.
[2]	Path planning	To present an energy-efficient strategy to avoid static and dynamic collisions with minimum energy required for drones to reach their destinations safely.	The gradient-based approach is utilized in the proposed algorithm for fast and quick convergence.	The results validate the efficiency and accuracy of the proposed algorithm in a dense environment that involves high collision risk with obstacle relative speed up to 10 meters/sec.

that would help to minimize deformation of the swarm's formation while providing solutions to avoid obstacles. There are also other papers that used a similar approach targetting to have a a very close surveillance of obstacles

IV. Conclusion and Future Work

The concept of Internet of Drones (IoD) provides a number of advantages that can be applied both in the military and civilian environments. Areas of applications such as transportation, agriculture based systems, entertainment, weather monitoring, healthcare systems and road hazards monitoring are very promising due to their main contribution for the sustainable development. Nevertheless, there are dynamic or statics obstacles in the sky that can hinder the overall performance of drones on their missions. In order to avoid those obstacles can be achieved by applying collision avoidance techniques while the drones are on duty. In this paper, we presented an brief survey of collision avoidance systems for the internet of drones. We have reviewed the current literature review ranging from the year 2010 to 2021. We provided a discussion discussion and analysis of selected articles, especially most used techniques including video based systems and swarm based intelligence approaches. In the future work, we intend to provide a detailed discussion of current literature by focusing on different AI and ML based techniques.

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