PERFORMANCE AND EFFICIENCY ASSESSMENT OF DRONE IN SEARCH AND RESCUE OPERATION

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Abstract. With the development of technology, human beings have successfully predicted and prevented the damage caused by natural disasters. However, due to climate change, society has witnessed the rising actions of forest fire, earthquake, tsunami, etc., and there are many which people cannot prevent, and the level of dangerous situations are increasing rapidly for the Search and Rescue (SAR) operation. Not to mention, more and more people are turning their attention and hobbies to exploring wilderness where they might get lost or, worse, get injured. For that reason, to raise the chance of survival for the victims and reduce the risk for the search team, the use of Unmanned aerial vehicles (UAV) has been proposed. The plan is the headquarters will deploy a fleet of drones to get into the areas where human cannot enter easily and then report the situations as well as the condition of the victims with images and videos. In most research papers, it seems very promising; however, there is still much work that needs to be done. In this paper, some of the features which included for future researches are which algorithm is the most optimal, what standard structure should be used for the drones so it can complete the missions under any kind of circumstances, and how to set up a communication line that guaranty the effective to reduce the level of miscommunication.

Keywords: UAV, AI, drone, search, rescue, efficiency

1 Introduction

The term search and rescue (SAR) has been a challenging activity, especially recently when people are witnessing many natural disasters such as volcanic eruptions, earthquakes, and hurricanes. In addition, accidents are sometimes caused by humans' carelessness and irresponsibility. In search and rescue scenarios, time is often the most critical factor as the life of victims are at risk [1]. For that reason, it is crucial that operators need to work on the SAR operation to find the most optimal solution. The idea is to use drones with artificial intelligence (AI) to help with the searching procedure. With a fleet of drones, people can scan a considerable area in

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a short amount of time, reducing the amount of cost and generating a safer working environment. The plan works in most articles; however, the proposal has encountered some issues. Inspectors need to figure out the best way to do this within the battery life of the drone fleet for them to have the best performance. Another barrier is communication between the fleet and the control command center since the rescue area can be significantly distant [2]. The purpose of this paper is to gather information about the effective use of drone fleets and modify some of its features to maximize its productivity in search and rescue operations. The paper has four main sections: Introduction, where it talks about the benefit of the drones for the search and search operation, and then the related work section, which describes the works in the past as well as what kind of data had been collected. After a review of what has been done by the previous researchers, this paper will propose some of the ideas for future work in order to suppose this proposal. Last but not least, it is the conclusion.

1.1 The use of drones for search and rescue operation

The use of drones has dramatically exceeded the expectations set for them. Drones have proved now and again that they can perform tasks with much greater efficiency and speed rather than ourselves. Furthermore, it has been an enormous relief that executives do not have to put humans in harm's way to complete taxing tasks. The development of drones is still in its infancy, so engineers still have more to gain from working on them. Hence, their use in search and rescue missions will make human missions obsolete, and doing so will significantly decrease collateral damage and save the lives of both victims and rescuers. One of the prominent reasons drones are better suited for SAR missions is that they can work 24/7 non-stop on any terrain or environment. [3] The versatile designs that exist as well as the designs that operators can yield from another development guarantee the manufacture of powerful drones that can decrease the number of lives lost in these missions in an immense amount, not to mention the fact that the consistent upgrades in their analogs, drones are becoming easier to use by the day. Moreover, various innovations are promoting the growth of the drone industry, a plethora of innovations are frequently being released to meet humankind's needs; Bluetooth low energy technology is one example. [4] Additionally, for every search and rescue operation, the critical factor is time. The rescuer needs to be responsive to the victim's area as quickly as possible to lower the level of danger and give necessary assistance if needed. Moreover, because of that, drones will be an optimal solution as it is easy for them to get into the areas where it might take days for on foot rescuer to get in and report the situation to the headquarter with images.

1.2 The use of AI in deploying drone for search and rescue operation

The discussion of using drones for search and rescue operations is getting more attention due to the development of technology and the efficiency of drones. The drone has significant benefits in terms of time as well as resources. Therefore, engineers must minimize or eliminate traditional search and rescue operations and focus on developing new methods. The use of drones in operation is not about sending a fleet to the located victim's position, but it is more about communication. Each drone needs to collect and exchange information so that the search and rescue operation can reach its best performance. The drones should follow a specific algorithm so that each of them will have a different mission as well as be able to calculate the fastest road to the victim's locations. For example, it will be unwise for two drones to appear in the exact location and have the same task. Each of them is a piece of a puzzle, and together with the right algorithm, they can gather enough information to finish the mission, which is to find the victims. In addition, it will not be economically efficient if supervisors need a whole team to operate the drone fleet. Operators do not need a group of people to decide where each drone should go while questioning if an area is covered yet. For such reasons and to decrease human errors, AI is crucial for drones. With artificial intelligence, every drone will have its position and function. Therefore, controllers will not have to worry about data duplication or miscommunication. Administrators can minimize the human resources since they might only need one to two people to monitor the process and transmit the necessary information to the ground teams.

2 Related work

There have been many works related to this topic. Most of the works focus on specific natural areas with a wide range of areas such as sea or forest. Furthermore, it is effortless to understand since humankind has been witnessing a considerable amount of missing planes recently. The works below are some examples in which drones' application is used in search and rescue operations.

2.1 Experiment

Now let's take a look and see in what kind of situations UAV brings the best result. Doing routine testing and lucid experiments are essential if people wish to have a better understanding of what needs to be developed more and what should be maintained [5]. Typically, the area where operators need to use drones is enormous. In the article "Autonomous Drones for Assisting Rescue Services within the context of Natural Disasters," it is reported that authorities are using UAVs to rescue the people who suffer from natural disasters. The plan is to use drones to get places where humans cannot get access, and then they will scan and send the image

back to the base. From that, searchers can make a 3D image like in figure 1 and figure 2 and locate where the victims are, and make an optimal plan to rescue. Also, in this article, the authors have pointed out three specific sub-tasks for the UAV to perform: Detect people, evaluate the group's composition, and estimate the direction position of the group and its velocity. [6] [7]

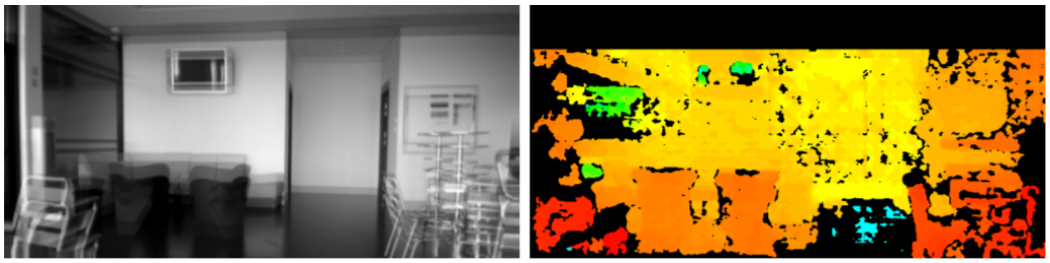

Fig. 1. Dense3D reconstruction The overlaid rectified images before and after the height change visualize the precision of the estimated camera motion (left). Therefore, any standard implementation for distance reconstruction, e. g. [12], may be used without modification (right).

Fig. 2. Sparse3D indoor (left figure) and outdoor (right figure) reconstruction based on a few dozens of points. Blue/purple lines show optical flow vectors consistent/ conflicting with the camera's motion. The points in color represent their longitudinal distance – red indicates 1 meter or less, cyan for 10 meters or more. A larger green circle marks the flight direction targeted by the drone, which is computed according to the furthest possible distance with no potential obstacles

Moreover, in the article "Intelligent Drone Swarm for Search and Rescue Operation at Sea," the use of ships and helicopters has wasted a tremendous amount of time and money; therefore, they have proposed a solution which is using the drone. The plan is to launch a fleet of UAVs to search for different ranges of area. This idea will increase the chance of survival for the victims since operators will only need to use the same amount of time (maybe less), but they can look for a wider area. Studies propose optimization techniques for SAR operations which present

a search heuristic that minimizes the time to find a single stationary entity on a given area. [8] [9] [10]

In addition, another article [11] has proposed the plan to search the missing people in large swaths of underpopulated wilderness. This is brought up because the number of people hiking to explore nature has increased rapidly. The idea is still using drones to search for missing people, but this time, they will attach a heat camera so it will navigate the lost people by their heat signature as shown in Fig 3.

Fig. 3. A drone enabling remote collaboration between an outdoor user and a remote (indoor) user. Such a system could be used to support remote collaboration in wilderness SAR.

As mentioned above, it is a huge challenge when people get lost or injured in a wilderness as the terrains can make it extremely difficult for the Search and Rescue operator to get to their position on time. Therefore, to minimize the time and the risks, Yunus Karaca and his team have proposed an idea where they use the drone to search and reach the victims [12]. They conduct an experience in a mountain environment using a simulation model (as shown in Figure 4). They focus on comparing the amount of time for two operations which are the Classical Line Search Technique (CLT) and the Drone-snowmobile Technique (DST), in three categories with $p < 0.001$ for a,b and c: First human contact, Total Searched Area and Searched Area for a minute. The CLT was more about human resources since

the search was by foot to reach the victims. Meanwhile, for the DST, the search was performed by drone as shown in Fig 5, and the victim reached by snowmobile.

Fig. 4. The simulation where an unconscious victim in snow-covered ground was enacted 10 times for each group using a 180 cm shop window mannequin to represent the accident victim [12].

The term "search and rescue operation" refers to situations with life and death, and the working conditions are hazardous. However, at this moment, communities are suffering from COVID-19 and are witnessing millions of people die because of it. Even though this situation is not expected for search and rescue operation, it is a life-threatening circumstance. Researchers have found some of the practical applications of AI and drones to identify people with COVID-19 symptoms and immediately put them in quarantine if necessary. Scientists are on the path to finding the cure; however, before they can do that, it is essential to minimize the consequence by keeping distance and wearing masks. These are the most effective ways, but it is not enough. A plan using AI and drones has been suggested [13]. First, drones use AI to detect the people suspended from COVID-19; then, AI will judge based on their X-RAY scan of their lungs, their blood test, the place they have traveled, and the temperature. Figure 6 below are the proposed framework

Fig. 5. The model of drone used in this experiment was DJI Phantom 3 Pro

in the article [4] by Mr. Maghded and his team. The first layer is responsible for FPR reading data from the sensor. It will read the captured CT scan images of the lung through using the smartphone camera, getting the inertial sensors measurements during 30-second sit-to-stand, as well as recording cough voice samples through microphone voice measurements during a series of cough, and finally, it will scan for the temperature sensor measurements during fingerprint touching on the smartphone screen. The reading of these samples is based on the symptoms from the COVID-19 patients. The second layer is structured to construct the on board smartphone sensors, including reading intervals, image size, timer resolution, etc. The third layer provides the calculated symptoms level, separately, and is then stored as a record input to the next layer. The last layer is to apply ML techniques to predict the COVID-19. The ML techniques could be used according to the nature of the recorded data. In order to increase the reliability of the result, the recorded data and the result will exchange in the cloud. If executives are managed to get more people using this framework, then the data-set will be larger, and the result will be more trustful.

Another way to prevent the spread of COVID-19 is to decontaminate the area where people with Corona viruses are permanent residents and their visited location. Many countries are using the chemical for the purpose of sanitizing, but there

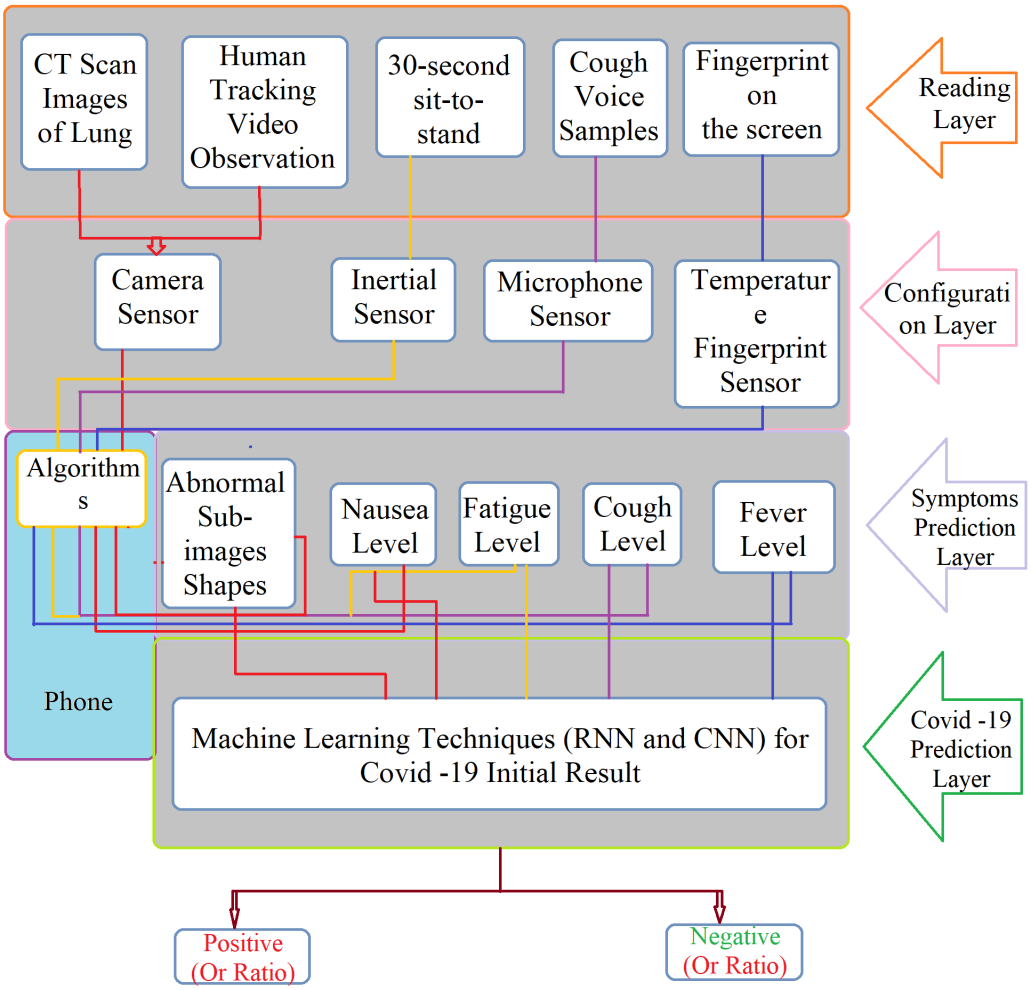

Fig. 6. Framework for AI-based Screening method

is a problem with using human resources since it takes too much time. Therefore, the idea is to use the drone to spray each place, which will cost half of the time. In the article [14], the author has shown that for a big country like India with a mass area of 3.28 million sq.km, it will take more than one hour for manual spraying compared to 15 minutes using drone (as seen in Figure 7).

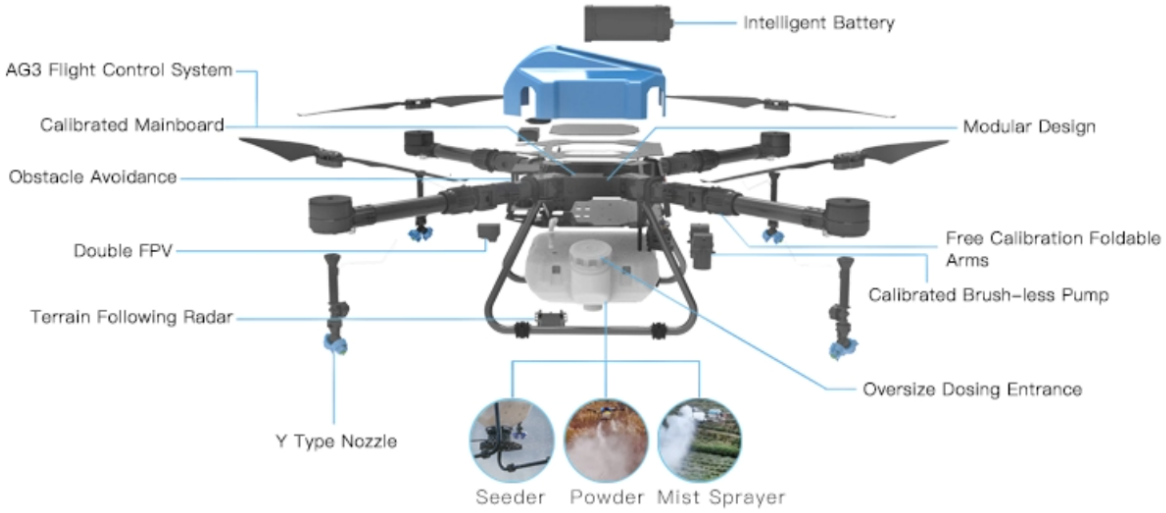

Fig. 7. Corona Killer Drones Disinfecting in India

Above are some examples which research made it very clear to understand and very persuasive about using the drone and AI to serve search and rescue purposes. There are more, but the most common thing is that they use drones and AI to minimize the time of the operation and increase collaboration and coordination while performing SAR tasks. [15]

2.2 Results of the experiments

- It is noticeable that the chance to be found for the people who are in danger using drones is much higher since the drone will be able to cover a much larger area, compared to the traditional way as in table 1 and table 2.
- Unmanned aerial vehicles will ensure the coverage of a large area in less time, reducing the impact of the limited battery capacity. As one can see in table 1 and table 2, this is the data which was found in the article [12] which demonstrate the effectiveness of using the drone for search and rescue operation. It is easy to notice a vast difference between traditional way versus drone search in three

categories. As a result, it takes less time for drones to search and find the missing person than traditional solutions.

Table 1. Characteristics of classic search in the mountain rescue scenarios

Operation No.	CLT		
	First Human Contact (min)	Total Searched Area (m^2)	Searched Area for a minute (m^2/min)
1	39	66408	1702.8
2	53.1	78209	1475.6
3	67.1	88664	1323.3
4	95	120891	1272.5
5	50.2	85861	1717.2
6	95.2	104479	1099.8
7	54	98385	1821.9
8	61.1	77378	1268.5
9	59.1	87980	1503.7
10	56.1	99375	1774.6
Median (25-75%)	57.3^a (52.3 – 74.0)	88322.0^b (78001.3 – 100651.0)	1489.7^c (1271.5 – 1731.6)

– Drones will give operators a better look at the scenario. Instead of just seeing trees and the outside context, controllers will be able to have a closer look and know what is happening inside. From that, operators can make a better judgment about the situation and take effective action [16].

– Using Drone will reduce the possibility of a rescuer getting injured or dying while on duty. Due to the lack of adequate information about the victim's situation, rescuers might cause more harm to the victim and themselves [1]. During the operation, the rescuer will have to remove barriers; however, they are not fully aware of what might happen if they clear the way. Therefore, it is possible for them to injure themselves and the victims. For that particular reason, it will be safer to use drones to locate along with estimating the most optimal pathway to reach the victims. Drones can provide a clear outlook for the rescuers so that they can perform with an adequate grasp of the victim's situation while maintaining their safety.

Table 2. Characteristics of drone search in the mountain rescue scenarios

Operation No.	DST		
	First Human Contact (min)	Total Searched Area (m^2)	Searched Area for a minute (m^2/min)
1	7.7	168395	28065.8
2	8.2	217624	33225.1
3	8.5	239602	35080.8
4	11.2	310981	32734.8
5	5.6	192224	49162.1
6	13.1	346268	30294.7
7	7.4	144480	25302.9
8	4.2	138945	54488.2
9	9.7	266722	33340.3
10	12.9	313525	27968.3
Median (25-75%)	8.4^a (6.9 − 11.6)	228613.0^b (162416.0 − 311617.0)	32979.9^c (28041.4 − 8601.1)

2.3 Limitations

- Battery Life: These drones can only work in such an amount of time before they need to go back to base and charge again. It is noticeable the biggest weakness of drones as it might affect the effectiveness of the task.
- Hardware and software issues have to be addressed: which algorithmic architectures to adopt? This question contains the answer to many problems. It is imperative to decide which algorithm in drones will be used since with the suitable algorithm, operators can find the best path (which mean with the shortest flying time but still able to cover the entire area) for the drone, and they might even solve the battery issues Which embedded system configuration is the most suitable one? The drones built, which are currently common use, are easily attacked by outside factors, and there are no protection layers for essential parts such as the wings.
- Camera and sensor: what kind of camera has the best weight and is able to give users the best visual of the situation no matter what the scenario is [17]. This is very important as operators need to remember that the place where they send the drone fleet to scout is very dangerous. There are some factors that can interfere with the view, such as heat, smoke or fog, etc. which will be challenging for them to detect the location of the victim if operators want to

locate them using heat signature and terrain that will become quite challenging for the controller to go in and collect information. The current use cameras are working correctly but only in a transparent environment. If the view is blocked, then the drone fleet is useless [18] [19].

- Communication: The communication capacity due to the limit of LoS (Limited Line of Sight) from the base on the ground to UAV, engineers need to consider that the wireless communication will not be strong enough to support the bandwidth requirements after few kilometers [20].
- Last but not least, how can a drone help to appease people in critical conditions or to provide helpful information which might help them stay alive? This is also an important task because the victims need to keep calm to make good calls, but can they do that when the only help they can get is from a drone? The answer to this is still unclear, but it is straightforward that the victims will be comforted if they see an actual human being. Therefore, making a drone able to appease people and give them helpful guidance so that they can survive is extremely necessary.

3 Proposal for future works

This proposal is promising as it will reduce the time and the risks for both the victims and the rescuer. However, there are still many works that need to be done.

3.1 AI Algorithm for the drone fleet

What algorithm should engineers use? It is easy to notice that there has been many articles and experiments about AI algorithm for search and rescue operation, and each of them has their strength as well as weakness. Based on the research from the existing articles, this paper found out that their algorithm might only work best in their stimulation situation since that algorithm is created to serve their need. People need to do more research so analysts can find out which algorithm will fit all the scenarios. This is challenging work, but researchers believe that it is necessary. It will affect the effectiveness of the mission if operators have to consider which algorithm should be used every time they encounter it. When the situation is life-threatening, time is critical. Because of that, executives need an answer or algorithm which will immediately respond no matter what the environments are. Moreover, the algorithm should also assess the drone's condition as when a drone is having technical problems such as low battery or malfunction of the camera and it needs to come up with a solution. The idea of deploying drones for search and rescue operations will become more practical if scientists manage to come up with an optimal algorithm.

3.2 Equipment and architecture

- Firstly, what kind of battery will provide the best lifespan? It is economically unwise to replace the drones instead of finding the appropriate battery that can enable the drone to fully function. In two or three hours drones run out of battery and they need to be charged. It is hard to predict the time for an operation to end. Every operation needs eyes on the sky as long as possible to observe activities and changes that might endanger the victim or the rescuer.
- Secondly, it is challenging to decide which material to use for the drones. Operators encounter several unpredictable variables during the operation. The drone's building material should be light enough so that the weight may not affect the drone, and it should be strong enough to enable the drones to complete their missions. In addition, the material should be water-proof so that water may not affect some of its functionalities.
- Thirdly, what should be the standard structure for the drones? There have been many models for drones released each year. Even though some of them are made for search and rescue purposes, they are not optimal since the operator has to consider the situation before those drones can be deployed. The idea is to have the drone model ready for any circumstance. In the article by S. P. Yeong [21], the author has pointed out some of the advantages and disadvantages for a different type of drone built-in table 3. Each drone has its owns unique pros and cons, and in order for UAVs to be ready for search and rescue operation, the researchers need to come up with a model that can incorporate all the necessary strengths and limit the weakness so that the drones will reach their maximum potential.
- Fourthly, what kind of communication device is suitable to apply? If the communication line is not stable, the operators will only receive piece of information, making it very confusing while endangering the whole operation. Therefore, it is essential to insert the right equipment to ensure the communication line may not get interrupted.
- Last but not least, it is also necessary to pay attention to the quality of the images and videos. The primary purpose of using drones is to collect information about the victim's situation by searching a large area and locating the missing person in a short amount of time. For this reason, everyone can not ignore the fact that drones must send images and videos of a high quality so that the headquarter fully understand what they are dealing with. Furthermore, researchers raise the following question regarding image and video quality: what kind of camera should be used? The camera for this procedure needs to meet these criteria: always assure the images and videos are clear to be seen and understood and, working properly under any situation, and be able to withstand certain hits from outside impact if necessary.

Table 3. Advantages and Disadvantages of different type of drone build

Drone Type	Advantages	Disadvantages
Fixed-wing	• Long range • Endurance	• Require an amount of space for horizontal take-off • Less maneuverability compared to VTOL (Vertical Take-Off and Landing)
Tilt-wing	• Has the advantages of both fixed-wing and VTOL	• Expensive • Complicated technology
Unmanned Helicopter	• VTOL • Maneuverability • High payloads possible	• Expensive • Require high level of maintenance
Multi-copter	• Expansive • Not difficult to launch • Light weight	• Limited payloads • Easy to be influence by wind

4 Conclusions

In conclusion, the proposal of using drones to serve search and rescue missions is very promising. There are endless possibilities with what drones can achieve. Still, there are many things that need to be done as the incorporation of drones with artificial intelligence is currently not widely used for search and rescue operations. This paper has pointed out some of the limitations and works that are needed to be done in the future based on other research papers and their results. Their works and this study intend to shorten the gap between the problem and solution. Since this concept is still a proposal, it is facing many difficulties in order to make it more reliable and make sure it works properly. In the future, in order to avoid doing the same experiments and collecting the same database, the research papers need to approach in different ways. From the articles for this paper and the result conducted from related works, there exist some similarities, such as the simulations that they are using are too specific, which might not be reusable for other contexts. Furthermore, authors are paying lots of attention in comparing the time between the traditional and drone methods while little do they remember that they also need to develop other aspects such as how should the drone notice the characteristic of humans or how should they respond to the headquarters when they found the victims? This is a promising idea; however, we should not rely on the development

of modern technology; future researchers need to reinforce the formal data as well as make it reliable and at the same time, consider about every other aspect of this idea as mention in the section above so that the plan of using the drone in search and rescue operation will be executed in a short time.

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