Literature Review on Employment of Unmanned Aerial Vehicles for Disaster Management

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Abstract

The focus of this study is to present the importance of Unmanned Aerial Vehicles (UAVs) for disaster management. UAVs are fast and highly customizable. They can play a significant role in disaster management. They can be used for assessment of the situation, delivery of supplies and locating people. Fast and efficient assessment of disaster-affected regions can be done using UAVs. This will help in faster relief and recovery. It is essential to select the appropriate type of UAV, along with its additional features, based on the requirements. Also, various parameters like cost, speed and height at which the UAV should fly must be considered.

Keywords : Unmanned Aerial Vehicle (UAV), Drone, Disaster management, Post-disaster assessment, Pre-disaster preparedness

1. Introduction

Over the past few decades, the number of disasters that have occurred across the world has increased exponentially. The disasters may be natural or man-made, but the effects of both have caused significant loss to life and damage to people and property. It is crucial that the effects of these disasters be reduced to a minimum. Disaster management is the process of reducing the damage done by any disaster and working on fixing the damage as quickly as possible. Disaster management consists of four parts: mitigation, preparedness, relief and recovery (He and Zhuang, 2016). All parts are crucial for reducing the damage caused due to a disaster. Mitigation and preparedness must be done before the disaster has occurred while relief and recovery would be during and after the disaster respectively.

When a disaster has occurred, there is a high possibility that many roads are damaged and conventional modes of transport would not work. Hence, motorbikes and helicopters are used for the assessment of the region along with transportation of people as well as emergency supplies. However, this can be slow and expensive. Thus, UAVs can be used in such situations. They are faster and more efficient. Therefore they can reduce the damage and help save lives.

A UAV is an aeroplane which flies without a pilot on board. Its applications include delivery, surveillance, photography, journalism, etc. This paper aims to find ways to employ UAVs to areas affected by natural or man-made disasters, i.e. for all pre-disaster preparedness and prediction, post-disaster assessment, and recovery. For areas which are inaccessible by trucks, cars, etc., they are instrumental. UAVs with a high load bearing capacity may also be used for emergency package delivery in these areas. Since they have a wide viewing angle, they can be used for spotting people stranded in these areas and collect information about the damage to roads and property. UAVs are, put, very useful as an application to disaster management.

Exhaustive research has been done on many aspects in order to employ UAVs for disaster management. The research has been broadly divided into the following categories:

- General applications of UAVs for Disaster Management
- UAVs for Search and Rescue operations
- Routing for UAVs
- UAVs used in Earthquake
- UAV-aided Emergency Networks for disasters

In this review paper, various applications of UAVs to disaster management and their parameters for the selection of UAVs have been reviewed. In section 2, we discuss the extensive research done on applications of UAVs in the above-given areas, optimising UAV parameters, and using the appropriate type of UAV based on the application. A comparative study of the 19 papers was done, and conclusions were then drawn. Conclusions aimed at the current findings and future scope are presented in section 3.

2. Literature Review

UAVs are aerial vehicles which do not have a person onboard. They are remotely controlled by a person nearby in the line of sight or by someone from far away as well. They can also be driven automatically. UAVs are also known as Drones and Remotely Piloted Aircraft (RPA). UAVs can be of various types and have multiple sensors based on the requirement. They can be classified based on various characteristics like flight type, size, operator, and level of automation (Kim and Davidson, 2015).

- Classification based on flight type:
    1. Rotorcraft UAV: These are UAVs with two to eight rotor propellers. Rotorcraft UAVs can hover at any height. This helps in taking better photographs or videos for assessment of a region. They can also take-off and land vertically. However, these types of UAVs consume more energy; hence battery life is minimal. They do not have large load carrying capacity.

2. Fixed-wing UAV: These have rigid wings with a predetermined airfoil. They have longer battery life, hence can cover greater distances. They have better load carrying capacity. However, they cannot hover and need a space for take-off and landing. Small fixed-wing UAVs are thrown by hand for take-off.

- Classification based on size (Payload Size):
  1. Large: up to 200kg (internally) and 900kg (in under-wing pods)
  2. Medium: up to 50kg
  3. Small: less than 30kg
  4. Mini: up to 5kg
  5. Micro and Nano: less than 5kg

- Classification based on the operator:
  1. Civilian-operated UAV: They are small sized UAVs that are used mostly for recreational purposes and videography.
  2. Military UAV: They are correctly used for military purposes which may have weapons onboard. These are occasionally used for civilian purposes like search and rescue operations.

- Classification based on the level of automation:
  1. Remote controlled: An operator must direct the UAV using a remote, phone, laptop or tablet during its entire flight. It is flown by Visual Line of Sight (VLOS) or First Person View (FPV).
  2. Autonomous Control: The operator uploads the path and directions before the flight. The computer will direct the UAV and onboard sensors aid in avoiding obstacles.

Research methodology conducted for literature review is as follows. From the extensive research, the literature review is based on peered reviewed papers of the following publishers: IEEE, Elsevier, Scientific Research, Springer, Wiley, Wiley-Blackwell, Taylor and Francis, MDPI, and Transportation Research Record

From the above-given publishers no textbook, conference proceedings, white papers were considered for the literature survey. Only journal papers have been considered for a literature survey; even PhD thesis have been excluded in the literature survey. Nineteen relevant papers were considered on UAVs for disaster management. The database available from the university has limited the number of papers reviewed for this research paper.

- General Application of UAVs for Disaster Management

Clarke (2014) describes the different types of remote-controlled and autonomous UAVs. Factors used to decide between these are type of disaster, magnitude, area affected and population (Restas, 2015). Clarke (2014) discusses the advantages of UAVs over conventional modes of transport for the delivery of packages, and surveillance of places. According to Erdelj et al., (2017), for the first stage, i.e. preparedness, UAVs are efficient in the collection of data which may then be used for predicting future conditions. Depending on the kind of disaster, the ways of recovery differ, but for most hydrological and climatological types of disasters, UAVs may be employed for the second and third steps of disaster management, i.e. preparedness and relief respectively. Decisive actions must be taken to avoid misuse of UAVs by establishing a set of rules or guidelines for conduct (Clarke, 2014). An example of pre-disaster applications are UAVs being used to monitor the radiation levels at the Fukushima Daiichi nuclear power plant and volcanic activity in Indonesia (Kim and Davidson, 2015).

He and Zhuang (2016) state that disaster management can be divided into four categories: mitigation, preparedness, relief and recovery. They show that when disaster magnitude and preparedness are small, relief can increase with an increase in preparedness. Work has also been done for forming a chain of supplies for post-disaster management by Noham and Tzur (2017). A mixed integer programming (MIP) model is constructed, an exact solution method is employed for small situations while a heuristic algorithm is employed for large-scale situations. Chowdhury et al. (2017) constructed a continuous approximation model for minimising the cost to help affected areas. They also conducted numerical experiments in a few regions to validate the results from the model. A unique optimisation model proposed by Rabta et al. (2018) takes into account the priorities of locations and those locations with the highest priorities are served first.

- UAVs for Search and Rescue operations

Search and Rescue personnel are exposed to medical and traumatic conditions due to the nature of their work (Niedzielski et al., 2018). This may be avoided by using UAVs for locating people instead of conventional methods. They are much faster and more efficient as compared to conventional methods. They can be equipped with various sensors like thermal sensors and can be programmed to follow an optimised route in order to locate victims at the earliest.

An autonomous UAV with a pre-decided route aimed at reducing the time taken for the finding was used to find snow-covered bodies in mountainous regions (Silvagni et al., 2017). It was found that navigation accuracy is typically within 2 m and achieved localisation accuracy is less than 1 m. The best performances were obtained when wide areas needed to be surveyed. Sánchez-García et al. (2019) derived a Particle Swarm Optimization (PSO) algorithm, which was derived from nature (e.g. bird flocks). It was described and then applied to the UAV network. Simulations were then run, and it was found that the dPSO-U algorithm can discover some of the victims fast. It also helps the UAVs converge faster. Niedzielski et al. (2018) conducted a real-time field experiment with a fixed-wing micro UAV, named eBee, which was manufactured by senseFly and equipped with the Canon S110 RGB camera. The Search and Rescue Unmanned Aerial Vehicle (SARUAV) system was based on two modules. The first module used Geographic Information System (GIS) tools and was based on a ring model and mobility model. The second model was based on the nested k-means method.

- Routing for UAVs

For search and rescue operations, routing of the UAV is fundamental. When UAVs are used to look for SCBs, as done by Silvagni et al., (2017), the search time determines the condition of the person when rescued. This is why covering a large area in a short period is very important and crucial to the process.

Avellar et al. (2015) state that for UAVs which are controlled by operators, using multiple UAVs slightly reduces the time taken to cover a particular area. Also, if multiple operators are used for each UAV the time can be reduced by a significant amount due to the decrease in the setup time. One of the solutions for multiple UAVs in the sky at a time is to divide the airspace into layers according to the maximum speeds and loads (if any) (Coelho et al., 2017). The routing of each of the UAVs would have to be optimised, keeping in mind the routing of the other UAVs, in order to avoid clashing. Bravo et al. (2018) show that one of the most successful methods for routing is Partially Observable Markov Decision Process (POMDP). For larger areas, it shows a considerable increase in efficiency to employ this method which changes the routing based on real-time inputs from the UAV, as opposed to the traditional greedy algorithm method. Other than these, the other three methods also employed for routing are Mathematical, Random, Heuristic and Purposive Heuristic. The purposive heuristic method is found to be competent and much quicker according to the research done by Oruc and Kara (2018).

- UAVs used in Earthquake

According to Xu et al. (2014), after an earthquake has occurred, remote sensing becomes an essential method for obtaining information, relief response, and post-earthquake disaster management. For these purposes, due to their low-cost, flexibility, and because it is real-time, UAVs are employed.

Xu et al. (2014) used a UAV with a predefined path to assess an area after an earthquake. Tests had been previously run in order to find optimal parameters in different kinds of weather, and according to the weather on that day, the flight parameters were decided. Photographs received were good with high resolution and provided enough information for help to reach the region in time.

- UAV-aided Emergency Networks for disasters

In August 2011, the Pukkelpop festival got hit by a severe storm. Due to increased phone activity, the wireless network in the area went completely down (Deruyck et al., 2018). Since UAVs can be mounted with small base stations, they can provide a temporary solution not to cause increased panic in the area.

Deruyck et al. (2018) created a UAV assisted emergency network for a disaster scenario. The UAV was mounted with LTE femtocell base stations, and many UAVs were deployed and spread over the area, forming a network. Specific parameters like flight height and bit rate were changed in order to decrease the number of UAVs required.

Table 1: Referenced journals with the year of publication

Journal of Publication	Year
Computers & Geosciences	2014
Computer Law & Security Review	2014
World Journal of Engineering and Technology	2015
Journal of the Transportation Research Board	2015
Sensors	2015
Geomatics, Natural Hazards and Risk	2016
European Journal of Operational Research	2016
International Journal of Production Economics	2017
Computers and Operations Research	2017
IEEE Pervasive Computing	2017
Journal of Field Robotics	2017
European Journal of Operational Research	2017
EURASIP Journal on Wireless Communications and Networking	2018
International Journal of Disaster Risk Reduction	2018
Future Generation Computer Systems	2018
Journal of Field Robotics	2018
Transportation Research Part B	2018
Production and Operations Management	2018

Table 1 consists of the journals these papers were published in along with the years they were published in ascending order of the years of publication. We infer that between 2014 and 2018, various journals have published research papers on UAVs used for disaster management.

Table 2: Industry of referenced papers with country

Industry/ Application Area	Country
UAV, Disaster Management, Transportation	The United States of the America
UAV/ UAS, Delivery, Transportation	Brazil
UAV/UAS, Disaster Management	Serbia
UAV/UAS, Disaster Management, Telecommunications	Belgium
UAV/UAS, Disaster Management	Italy
UAV/UAS, Disaster Management, transportation	Austria
UAV/UAS, Disaster Management, image processing	China
UAV/ UAS	Australia
UAV/UAS, Disaster Management	Spain
UAV, Disaster Management	Hungary
UAV/UAS, Disaster management	USA
Search and Rescue Operation,UAV	Poland
UAV, Post-disaster assessment	Italy
Transportation, UAV, Motorcycles	Turkey
UAV, Path Planning, Disaster Management	Brazil
Disaster Management	USA
Humanitarian Logistics, Disaster Management	Israel
Vehicle routing, UAV	Brazil

Table 2 presents the area of focus of these papers along with the country of work. Research has been done in various countries all over the world.

3. Conclusion and Future Scope

UAVs can play a significant role in disaster management. Since they are much faster and can be of various sizes, they are easier to use and can help reduce the loss of life and the damage done during a disaster. The performance of UAVs shows that the rescue time, as well as cost, may be reduced. Since they have a more comprehensive view from above, they are instrumental in search and rescue operations. UAVs with a higher load-bearing capacity may also be used to deliver emergency supplies to places which are not accessible by road. Many modes of transport cannot continue because of the damage to the roads. Hence, UAVs can be used to collect information about the disaster-affected region faster and more efficiently. UAVs can be used to locate people lost or stuck due to the disaster in a shorter period. This information can be used to analyse what is necessary for saving the people and for a quick recovery from the disaster.

The UAV to be used for a particular situation should be carefully selected based on battery life, weight, load bearing capacity, sensors, automation or remote control, and many such factors. Each of its parameters like flight height, speed, the range should be optimised. The routing for these UAVs is also essential.

The studies did not consider wind factors for the UAV during flight. The use of thermal imaging may improve the possibility of correctly locating a person. Global Positioning System (GPS) is not consistently available in mountainous regions. More efficient communication is required between the operators and the UAVs. Collision with objects apart from other UAVs should be considered while planning its routing. Battery costs are also not considered. Due to the small battery life of UAVs, research on the possibility of recharging them mid-air, mid-operation could be done. The current UAV technology has several limitations such as limited payload and operations range due to energy constraints. Since they have limited flight timings, a hybrid system including trucks, Sport Utility Vehicles (SUVs), helicopters, and UAVs is the most important for disaster response.

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