A novel technical analysis and survey on disaster robots for flood search and rescue operations

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ABSTRACT

The advance in human-robot interaction brings out novel applications of the disaster rescue operations. Especially, the concept of search and rescue (SAR) assisted robot operations plays an extensive role in the natural hazards, such as earthquake and wild fires. Particularly, the SAR operations in the water-based drowning due to floods and boat capsize disaster are expensive and not fast. This paper presents a survey on various SAR based remotely operated vehicle's (ROV) related to airborne, under and surface of the water, such as unmanned marine vehicles (UMV) and unmanned aerial vehicles (UAV). In addition, the performance analysis of each UMV such as EyeROV TUNA, Saif Seas, iBubble, DTG3, Trident, Fathom One and SEAOTTER-2, is listed which helps to select the right UMV for the rescue operation at different water depths. Also discussed various SAR based UAVs like DJI Phantom-MAVIC 2, YUNEEC-H520 Hexacopter, Microdrones MD4-1000, DSLRProsMatrice 210 RTK V2 and AltiGator'sXena Drone for the flood and boat capsize operations. However, the usage of Syma X8 Pro UAV for the flood operations are worthy than Sea King SAR Chopper, which is a cost-effective operation.

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1. INTRODUCTION

In global flood incidents, the rescue teams are able to get most of the people who died during the flood rescue operations back. In fewer cases, the teams or individuals providing assistance found the victims alive. The most reliable flood rescue and management decision support system (FRMDSS) must equip the rescue teams to keep more people alive. We need to integrate advanced technologies like web-based geographic information system (GIS), artificial intelligence (AI), and the internet of things (IoT) to enhance the speed and accuracy of FRMDSS, enabling faster information dissemination for tracking and rescuing pupils in a shorter timeframe. The advanced early method will alert the local government and rescue teams so that rescue operations can be speeded up and victims and people who are at risk of drowning can be saved. Now, technology-driven automation procedures can make flood management more effective than manual response operations. Defence rescue operations related to natural disasters and war surveillance tasks use unmanned vehicles (UV) for a wide range of applications [1]. Especially drone-based flood rescue efforts, in particular, are very helpful and important to speed up the search and rescue (SAR) process. In recent times, the efficiency of SAR operations has increased due to the wide range of information and communication technology (ICT) applications, such as human-robot interaction (HRI) through unmanned vehicles. Researchers have been increasingly interested in how HRI can aid in disaster management for SAR activities due to climate change in the last 20 years. Especially the data collection plays a crucial role to excute SAR operation perfectly that reduces the rescue time and helps to save lives. The data collected from the disaster area by the remotely operated vehicle (ROV), also known as disaster robots (DR) or UV, is used to help rescue operations. DR do this by sending real-time data and other sense data to rescue workers. The reaction must be as quick as possible to get to all possible dangerous areas and find survivors. In general, the DR is classified into three different types, they are aerial remotely operated vehicles (AROV), surface remotely operated vehicles (SROV), and marine remotely operated vehicles (MROV). Effective management of SAR includes a wide range of tasks from different fields, such as physical, electronic, and canine investigation. The main goals are to:

a. Get exploited people out of falling buildings
b. Help victims and rescuers get back on their feet after a crisis
c. Look at and control any utilities that may have caused the problem and check for any dangerous materials
d. Evaluate and fix damaged buildings [2]-[4]

Especially for flood rescue operations, the best options are to use unmanned aerial vehicles (UAV), unmanned water vehicles (UWV), or unmanned marine vehicles (UMV). Generally, UAVs measure things like river runoff, floating items, and the direction of the water, among other things. The UWV or MROV then transmits underwater data, such as videos and pictures, which aid in locating victims and supporting crucial rescue operations. We gathered data in the form of images or frames, both above and below the water. The use of artificial intelligence (AI)-based computer vision techniques for flood rescue operations analysis will be so helpful in planning rescue operations within a short span of time. In addition to flood disasters, the SAR operation also utilizes terrain such as mountains and forests. Each of these areas has its own problems and challenges, such as energy efficiency, the global navigation satellite system, communication and deployment, path planning, avoiding collisions, moving quickly in confined spaces, and more [5]. Karaca *et al.* [6] discussed the importance of drone-based rescue operations in mountainous areas to find the victims. In addition, fire departments might use drones as tools to find out when forest fires will start. Flexible, low-cost, high-altitude remote sensing systems that are built on drones fill in data gaps and make manned aircraft and satellite systems better [7], [8]. At present, there is a growing need and significance for DR in SAR-based operations, with the aim of reducing response times and enhancing cost-effectiveness. Even though many drones are available, choosing the best disaster robot for flood operations is always challenging. Furthermore, the lack of technical analysis studies in the drone literature contributes to the increasing difficulty in selecting the appropriate drone or DR for flood reconstruction operations. The current study primarily concentrates on the crucial elements of UAV and UMV, which are currently in use worldwide for flood rescue operations, with a particular focus on their cost-effectiveness. This study selected limited and popular DR that perform faster and better flood rescue operations. The present work also demonstrated a cost-effective flood data acquisition method using the SymaX8 Pro UAV to monitor flood-prone areas on the Godavari River near Dhanammamarri, East Godavari District, Andhra Pradesh, India. The present work discusses a novel technical performance analysis of disaster robots, specifically UAVs and UMVs, to address SAR operations in flooding areas. The technical survey of UAVs and UMVs is based on frame resolution, range, depth, battery time, flight time, wind resistance, and AMSL. This work helps the researcher select the right drones for SAR operations in air and marine environments, especially in boat capsize rescue operations. We have organized the remainder of this work as follows: section 2 describes background work in human-computer interaction (HCI), search and rescue, unmanned vehicles, and convolution neural networks (CNN), as well as the tasks of SAR operations. Then, section 3 discusses the methodology and section 4 presents the classification of SAR robots for each specific task. Similarly, section 5 explains details of flood SAR unmanned vehicle analysis, and section 6 provides real-time SAR experimentation using a Syma X8 drone. Section 7 presents the results and discussion on the UAV and UMV impact with respect to SAR flood operations, and section 8 summarises the entire work with conclusions.

2. BACKGROUND WORKS

The concept of SAR operations using DR was first introduced by Murphy and Burke [9] in 2005, after the collapse of the world trade center (WTC) by terror attacks. For the first time, DR were used in order to search for the victims, which in turn helped with the smooth conduct of rescue operations. The present status and challenges in the human-robot interaction are discussed as follows: subsequently, all natural and manmade disasters have utilized the DR. For instance, Murphy *et al.* [10] applied the MROV to Minamisanriku and Rikuzentakata, Japan, for disaster recovery and observed that the DR plays a vital role in terms of economic and victim's recovery. Also expressed is the need to optimize according to stakeholder needs. In addition, Srivaree-Ratana [11] explained the necessity of the UAV for the effective management of flood emergencies with the help of Thailand's humanitarian assistance disaster recovery (HADR). Bejiga *et al.* [12] applied CNN to the UAV to recognize and track objects in the disaster area. To obtain high-resolution maritime rescue operations, Gallego *et al.* [13] equipped multispectral cameras to search for bodies in maritime rescue operations. They also proposed three classification methods: full image, a sliding window, and a precise localization method, and obtained the finest results regarding obtaining the best classification performance when combining green, red edge, and near-IR channels. As many SAR operations need to be performed and must be automated in emergencies. This will reduce time and speed up rescue operations for human survival.

The literature states that the SAR operation minimizes the rescue time and finds the exact geographic location of the victim using location-enabled disaster robots. The researchers focused on the HCI for rapid SAR disaster response operations. The HCI majorly concentrated on the evolution of the best pattern recognition methods with the inclusion of deep convolution neural networks (DCNN) for smart response services based on UAVs. Castillo worked to detect victims in SAR operations using template matching [14]. Ward *et al.* [15] explained human detection in the uncluttered environment of the Earth surface using UAV technology. Then, Bejiga *et al.* [16] described the application of convolutional neural networks for the Avalanche SAR operation based on the UAV imaginary. Next, Lopez-Fuentes *et al.* [17], [18] did an extensive review of computer vision techniques in emergencies. In recent times, the government of Andhra Pradesh has used drones for flood surveying and management. A survey was conducted on the Guntur flood using a UAV and the flood status was reported to the public and government officials [19]. The Sea King helicopter is widely used in SAR operations in flood disasters in India [20]. Especially for the recent flood rescue operations in the study area, the Indian Navy used the Sea King choppers [21]. Zhu *et al.* [22] proposed an in-depth examination of vehicle recognition in aerial pictures for SAR operations using deep learning techniques using single shrot detector (SSD), Fast region-based convolutional network (RCNN), and fast RCNN methods on the VEDAI-512 and DLR-3MP datasets (DJI Inspire 1 Pro) and achieved an accuracy of 88.7%. Liu *et al.* [23] verified the performance of the deep learning algorithms such as you only look once (YOLO) v2, sea surface height (SSH), and tiny face to identify the faces of birds on the little birds in aerial imagery (LBAI) dataset and achieved an F1 score of 92.5% for SSH. The dataset is a custom dataset captured using a UAV and categorized into three types of datasets.

Navigation, which involves guiding a vehicle safely to its destination without hitting other obstacles, is a major issue in autonomous SAR operations. Navigation includes task assignment, global path planning, and local collision avoidance. Hasan *et al.* [24] proposed an IoT-aided SAR communication framework for flood management to build an effective infrastructure-less communication approach that can quickly discover victims and facilitate rescue actions. The SAR operations for disaster management using the IoT based on mobile ad hoc networks (MANET), vehicular ad-hoc networks (VANETS), flying ad-hoc networks (FANETS), TV white space (TVWS) network, and delay tolerant network (DTN) have their own limitations. The classification of multirotor UAVs is the most frequently observed among UAVs. It harnesses the power of motors and propellers to create upward force by rapidly rotating them. The number of motors further categorizes it into four commonly used types: octocopter (eight rotors and propellers), hexacopter (six rotors and propellers), quadcopter (four rotors and propellers), and tricopter (three rotors and propellers) [25]. Modern methods include simultaneous localization and mapping (SLAM), centered on drones use LiDAR and IMU sensors to gather environmental data in real time. By filtering, segmenting, and registering LiDAR point cloud data, the computer can extract environmental features like walls and corridors [26]. Most of the UAV path planning problems include optimizing a path from the starting point to the terminal point using multiple parameters and constraints [27]. Obstacles and collisions affect UAV navigation. One cannot provide UAVs with an ideal environment. One can avoid path obstacles. Furthermore, numerous aerial robots function better and more efficiently than one. Working in groups might cause accidents [28]. UAVs must perform SAR operations in unknown conditions, such as GPS-denied or mapless areas. Rapidly-exploring random trees (RRT) uses randomized algorithms to build a tree-like structure by repeatedly adding nodes to quickly search the search space. The robotics community has embraced RRT. Robots integrate their environment perception sensors to actually apply the RRT algorithm [29].

Casualties in the maritime sector are rising. In the event of a marine tragedy, maritime authorities and operation centers are aiming to establish a speedy search for survivors at sea using UAVs in maritime SAR operations to limit search area extensions. Cho *et al*. [30] proposed numerous numerical experiments to verify the algorithmic performance of maritime SAR operations. Their experimental findings reveal that the RSH solves with a 0.7% optimality gap in substantially less time than a commercial solver. Climate change may cause urban floods after heavy rains. Urban development, aged infrastructure, and more impervious surfaces are worsening flooding. Custom flood modeling and prediction are needed to improve resilience and flood mitigation. Drone-focused, high-resolution 3D mapping data will be collected from several flying platforms [31].

3. CLASSIFICATION OF SEARCH AND RESCUE ROBOTS TASKS

The SAR robots can perform potential disaster rescue jobs as discussed below. The Figure 1 shows unmanned rescue vehicles could perform series of tasks [32], [33]. Search (situational): an action that is moved inside a building, in caves or tunnels, or in the wild in order to find someone who is hurt or possible dangers. The goal of the investigation project is to get things done quickly and effectively without putting the people who are helping or the victims in more danger. Acting as a mobilebeacon or repeater (communicate): to increase the range of wireless frequencies, make it easier to find people who depend on radio signals by adding more receivers, and serve as tourist spots so that rescues can stay put. Map-making and reconnaissance cover more ground than searching. It tells people about general situations of mindfulness and talks about the pulverized state. Providing logistics support: by automating the movement of goods and equipment from areas with lots of space to groups or delivery points inside the flood zone. Rubble removal (extract fatalities):Robotic tools or exoskeletons can help with this motion. The idea behind it is to move bigger debris faster than is physically possible while leaving less of a mark than a normal construction crane. Structural inspection (manoeuvre): so that rescuers can figure out what the rubble looks like so they can avoid more falls that could hurt people and decide if a building is safe to enter. By using robots, extra sensor packages can be brought closer and placed in more positive survey edges.

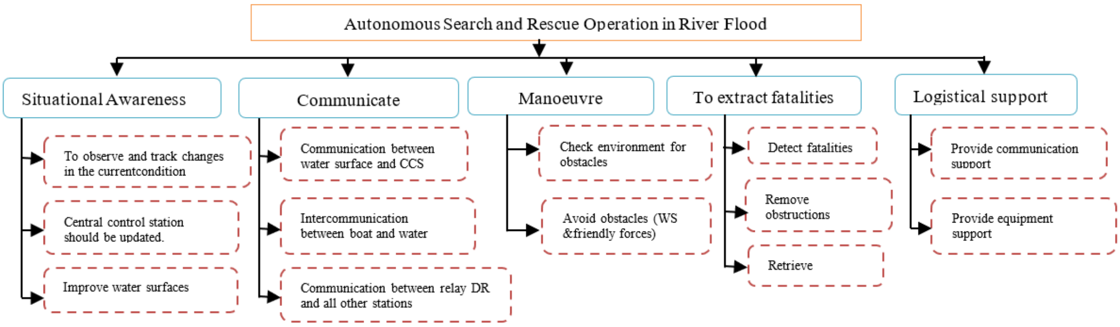


Figure 1. Functional hierarchy of flood SAR operations

4. METHOD

The present study has focused only DR related to flood SAR operations that includes only UAV and UMV (Figure 2). The methodology adopted to evaluate the performance of UAV and UMV is follows: Step1: DR is segregated into UAV and UMV. Step2: Collect the UAV parametric devalues regarding flight radius (FR) (kmph), payload (P) (in kg), flight time (FT) (in minutes), max speed (MS) (in kmph), max wind resistance (MW) (in kmph), AMSL (meters).

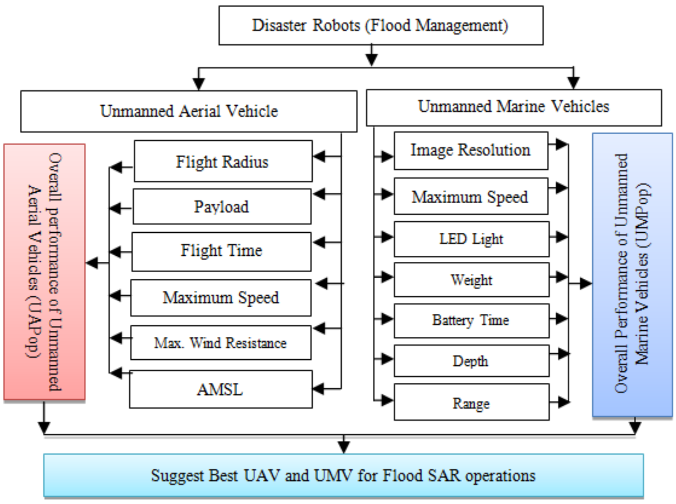


Figure 2. Method for technical analysis and survey on DR

Step3: collect the UMV performance paramteric data value such as image resolution (IM), range (R) (in meters), depth (D) (in meters), battery time (BT) (in minutes), MS, (in knots), LED light (LL) (in lumens), weight (W) (in kg). Step4: compute the overall performance of UMV (UMProp) and UAV (UAProp). And step5: to suggest the best UAV and UMV consider the highest UMProp and UAProp value to suggest the best drone for flood SAR operations.

5. FLOOD SEARCH AND RESCUE UNMANNED VEHICLES ANALYSIS

As discussed earlier, the UV is classified as UMV, UAV and unmanned surface vehicles (USV). Each one of UV has specialized applications. The UWV and UAV plays an important role with regard to flood SAR operations are concerned. Few of the flood rescue related UWV and UAV are discusses below.

5.1. Unmanned marine vehicles

These boats are also known as non-autonomous underwater vehicles (NAUV) or UMV. UWV, also referred to as "underwater drones," are any underwater vehicles capable of operating without human intervention. These vehicles fall into two categories: remotely operated underwater vehicles (ROUVs), which require human control from a distant location, and autonomous underwater vehicles (AUVs), which operate without direct human input. A type of robot would be in the final class.

5.1.1. EyeROV TUNA

EyeROV Technologies developed India's first underwater robotic drone at Maker Village, Kochi, which can transmit live video of boats and other submerged structures to aid in their repair and maintenance. Up to a depth of 50 meters, the robotic drone can explore and capture continuous HD video images of ship structures, undersea links, or extension moorings, eliminating the need for costly and risky manual inspections by jumpers. EyeROV UMV is tested on ship bodies, ports, dams, and atomic power plants to hunt and protect maritime mine locations and seas. Figure 3(a) shows the EyeROV TUNA UMV on the surface of water [34]-[36].

5.1.2. The Saif Seas

The UMV is GPS-enabled and manufactured in India. The water drone is watertight and has been tested for uprightness up to 10 meters of water profundity. In the event of damage to the frame and water passage, the defensive polyurethane froth will allow for negligible water entry, preventing sinking. The drone can carry a maximum of 100 kg of weight. It can give floatation to up to three individuals in a stationary condition. The current range is 3 km (observable pathway), extendable up to 10 km or even more, depending on the use and client requirements. The UAV operates at an extreme speed of 7 knots, while the on-board individual maintains a speed of 2 knots. Figure 3(b) illustrates the motion of the saif sea surface water rescue drone on the water's surface [37].

5.1.3. iBubble

The iBubble drone is the first autonomous wireless underwater drone, and it easily follows a scuba diver. The drone also tracks the diver's movements in real-time, and the incorporated sound navigation and ranging (SONAR) technology allows automatic obstacle avoidance. The drone, equipped with seven propellers, provides exceptional mobility and stability, enabling unique capture from various angles. The drone is particularly useful for SAR operations [38].

5.1.4. Deep trekker-DTG3

The DTG3 is a business-grade, smaller-than-usual ROV, structured with the deep trekker protected pitching framework for unmatched mobility. An inside HD camera with a 330-degree field of view can examine beneath, above, behind, or before you and see the live feed straightforwardly on your hand-held controller. With on-board batteries, you can work 8 hours on one 1.5-hour battery charge and never stress over dragging around numerous cases or generators to your jump locales. The DTG3 has a forward speed of 2.5 knots, with profundity evaluations of 100 m and 150 m; this instrument is perfect for submerged examinations of the surroundings. All DTG3 packages include the robust DTG3 ROV, which comes with a variety of assistants to cater to different applications and Figure 3(c) shows the DTG3 UMV [39].

5.1.5. Trident

Trident is a powerful underwater drone, and its compact design makes it portable to any place very easily. The drone transferred the underwater video data in HD with low latency. The drone is scalable, open source, and includes custom sensors or modules as add-ons. Propelled autopilot highlights and instinctive heads-up presentation help you feel comfortable at 100 meters [40].

5.1.6. Fathom wone

The Fathom One is an underwater wireless-controlled drone designed for submarine exploration and underwater video capture. The modular design allows for quick assembly and packing. The camera sensors capture high-definition (HD) video and stream it. In addition, high-intensity LED headlights allow for capturing underwater footage suitable for limited SAR operations, i.e., less than 100 feet's [41].

5.1.7. SEAOTTER-2

Controlled from the surface, the SEAOTTER-2 ROVs are highly versatile underwater drones ideal for SAR operations. These ROVs are ideally suited for a variety of applications, including pipeline assessments, stream and sea searches, dam reviews, oil and gas stage work, fish cultivation, and country security tasks. These can significantly reduce search times, as well as the risks and exorbitant costs associated with diving tasks [42].

5.1.8. AquabotixEndura

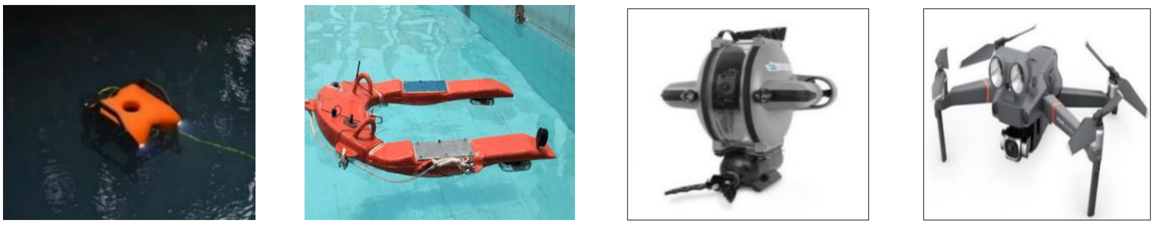
The Aquabotix is a small, easy-to-operate ROV with limited SAR applications. MIT and Oxford Universities jointly designed and developed the open-source application that incorporates the drone. It consists of five torque motors and excavates up to 300 meters in depth. Moreover, Aquabotix's UUVs can simultaneously take readings in multiple areas, enabling the naval force and its allies to identify, locate, and eliminate unexploded weapons [43].

5.2. Unmanned aerial vehicles

An UAV, also referred to as a drone, is an aircraft that operates without a human pilot on board. UAVs are a component of an unmanned aerial system (UAS) that consists of a UAV, a ground-based controller, and a system of communications between them. UAVs can operate at varying levels of autonomy, either being controlled remotely by a human operator or operating independently using onboard computers or smartphones.

5.2.1. DJI Phantom-MAVIC 2

In order to save lives, response teams frequently explore vast, testing, and unsafe territory. DJI drones bring semi-mechanized instruments that swiftly scout these districts, identifying those in danger without jeopardizing individuals within the group. DJI drone arrangements effectively search the sea for individuals who have become lost or adrift. Even in low deceivability, search teams can use warm and zoom cameras to clear substantial waterways, find heat marks, and start salvage. DJI Phantom fabricates a 3D model of the world while exploring it. Using a 3D model of its environment enables the automaton to make intelligent decisions about navigating around obstacles. Furthermore, real sense has the capability to remember its current state, which enhances the predictability of potential collisions. It isn't reactionary; if it stays away from an impediment once, it will recall the area of the deterrent and therefore know how to maintain a strategic distance (Figure 3(d)) [44].



(a) (b) (c) (d)

Figure 3. Drone; (a) EyeROV TUNA underwater drone; (b) Saif Sea rescue drone; (c) DTG3 underwater drone; and (d) DJI Phantom-MAVIC 2SAR UAV

5.2.2. YUNEEC-H520 hexacopter

UAV stages are rapidly becoming an accomplished partner for SAR ground teams. UAV stages are invaluable to ground teams. Probably the most widely recognized applications include exploring the path ahead for deterrents, locating unfortunate casualties, photographing remote accident locations, using airborne correspondence repeater stages, mapping territory, and inspecting crash sites. SAR experts are looking for new ways for each mission to integrate UAV stages into their activities. The innovation fabricates a 3D model of the world while exploring it. Using a 3D model of its environment enables the automaton to make intelligent decisions about navigating around obstacles. Furthermore, real sense has the capability to remember its current state, which enhances the predictability of potential collisions. It isn't reactionary; in the event that it stays away from an impediment once, it will recall the area of the deterrent and consequently know to maintain a strategic distance from it [45].

5.2.3. Microdrones MD 4-1000

The MD 4-1000 are fully integrated systems for creating 3D point clouds optimized for mining applications, land surveying, oil and gas, and construction. The microdrones MD 4-1000, specially used for SAR operations, also implemented end-to-end LiDAR solutions combining drones, a fully integrated software workflow, high-resolution cameras, and LiDAR payloads [46].

5.2.4. DSLR pros matrice 210

The DSLRProsMatrice 210 has a body with an ingress protection rating of IP43 for residue and water obstruction. Additionally, the DSLRProsMatrice 210 features self-warming double batteries, ensuring reliable performance in temperatures below zero. This implies that it will remain operational even in the harshest and most severe conditions, enabling it to adequately fulfill its intended purpose in basic modern applications. This encompasses a rigorous condition framework, vitality examination, building site mapping, and SAR operations. The FAA has set legitimate elevated scene lighting as a fundamental requirement for lawful night activities. Our inspire 1 first responder kit incorporates the DSLRPros night operations strobe light, which has a blaze rate of 60/minute [47].

5.2.5. AltiGator'sXena drone

The purpose of AltiGator's drones is to provide staff with cost-effective, continuous information and imaging, regardless of the time of day, under testing conditions, and without any potential risks. The infrared (IR) warm imaging camera, which can detect human body heat, aids in the search for missing people. This capacity incredibly builds the capacity to discover individuals or articles around evening time that might be covered up amid daytime activities [48].

6. EXPERIMENTATION WITH SYMA X8 PRO

The Syma X8 Pro drone collects two types of data formats to identify river and flood-floating objects. The Syma X8 Pro UAV cost-effectively acquired both images and video frames [49], [50]. Remote control allows for all-around rotation of the Syma X8 Pro aircraft. The Syma X8 Pro includes a GPS location framework, allowing for more precise hovering and review of the UAV at its takeoff point. The height of the UAV is 19 cm, whereas its width and breadth are 50 cm. The mobile phone and Syma FPV app synchronize the WiFi camera with a 2.4 GHz WiFi connection to transmit video and images. You can tilt the camera up to 90°, offering two distinct operating angles. It integrates functionality such as a power button, camera adjustments, hovering, rotations, GPS one-key return, flying right or left, and on-key takeoff. Protective gear protects the UAV from collisions and sudden accidents. Sensors such as barometric pressure, accelerometers, and 3-dimensional gyroscope sensors play a crucial role in the performance of the UAV. The Syma X8 Pro is the advanced barometric pressure technology improves image acquisition stability during hover functions and reduces noise and blurring caused by the aircraft's instability and shuddering [51]. An accelerometer estimates every single straight power that is chipping away at an article in units of millivolts per gram (mV/g) [52]. A MEMS gyroscope additionally depends on the fluctuating capacitance among silicon and mechanical components. However, with this design, the sensor produces capacitive changes with precise speed changes [53]. The Syma X8 Pro is tested on the Godavari River to collect images and videos of high definition quality (Figure 4).

Figure 4. Researcher operating Syma X8 Pro drone is flying on the Godavari river near Dhanammamarri, East Godavari District, Andhra Pradesh, India

7. RESULTS AND DISCUSSION

This section covers results on technical capabilities of unmmaned air and water vachiles. This section also presents a novel and important about operation cost of SAR drones in flood operations with discussion.

7.1. Unmanned marine vehicles technical survey

We conducted the UMV technical survey by evaluating the technical capabilities of different UMVs for SAR operations. Table 1 displays the comparative study of each UMV based on various statistical parameters. Among the eight UMVs, the DTG3 image resolution is very high, i.e., 4K, and the flight time of 480 minutes and range of 800 are excellent for SAR operations under water. These sorts of drones are useful for searching for drowned people and sinking boats that are under 200 meters deep. However, the cost of the drone is relatively high. With the exception of the Saif Seas, the rest of the drone operates both on land and underwater. However, the Saif Seas UMV operates solely on the surface of rivers or seawater, providing immediate rescue services. The Saif Seas UMV prefers to search in depth areas, where the SEAOTTER-2 proves to be the most effective option, with the AquabotixEndura following closely behind. The remaining drones, EyeROV TUNA, Trident, and Fathom One, are suitable for low-intensity flow rescue operations. While iBubble is the cheapest UMV of all, usage is also very limited. In (1) articulates the overall performance of unmanned marine vehicles (UMPop). Table 1 presents the detailed technical specifications along with performance statistics. Figure 5(a) shows the graphical representation of the overall performance of the UMPop and it is observed that the DTG3 performance is very high with 9895.5 units and Fathom One stood last with 1665 units.

$$UMV_{op} = Max(IM + R + D + BT + MS + LL) + Min(W) \tag{1}$$

Table 1. Performance analysis of the UMV

S.No	Name of the UMV	Image resolution	R (meters)	D (meters)	BT (minutes)	MS (knots)	LL (lumens)	W (kg)
1	EyeROV TUNA	1080p	30	100	180	2	6000	10
2	Saif Seas	1080p	3000	NA	90	7	NA	12
3	iBubble	480p	25	100	60	1.5	2000	9
4	DTG3	4 K	800	200	480	2.5	4400	13
5	Trident	1080p	150	100	180	3.89	360	3.4
6	Fathom One	1080p	100	150	60	3	270	2
7	SEAOTTER-2	1080p	500	500	External power	3	2200	19.5
8	AquabotixEndura	1080p	60	300	180	5	4400	6.8

7.2. Unmanned aerial vehicles technical survey

We conducted the UMV technical survey to assess the technical capabilities of different UAVs for SAR operations. Generally, you can attach the UAV cameras separately, based on your requirements and price range. Table 2 displays the comparative study of each UAV based on various statistical parameters. Out of the five UAVs, the Microdrones MD4-1000 boasts a very high wind resistance capacity of 44.2 kmph and a flight time of 45 minutes, two crucial parameters for executing rescue operations in the unfavorable climatic conditions of floods. The DSLRProsMatrice 210 RTK V2, with a flight time of 38 minutes and a wind resistance of 27 kmph, takes the next position. The DJI Phantom-MAVIC 2, the YUNEEC-H520 Hexacopter, and AltiGator'sXena Drone follow later. We also use the Microdrones MD4-100 for LIDAR surveys because of their relatively low cost compared to using airplanes for the same purpose. Moreover, the Microdrones MD4-100 UAV is very active in SAR operations but expensive compared with the other drones. Among all five, the AltiGatorsXena Drone is the cheapest and lowest-performance drone. However, the drone's usage and applicability depend on the disaster's intensity and geographical location. In (2) articulates the overall performance of UAVop. Figure 5(b) presents a graphical representation of the overall performance of the UAVop, indicating that the DJI Phantom-MAVIC2 has the highest performance with 6138 units, while AltiGatorsXena Drone has the lowest performance with 237.3 units.

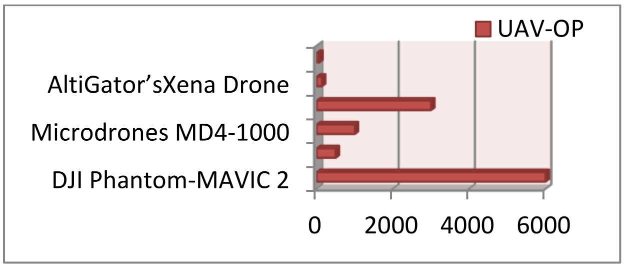
$$UAV_{op} = Max(FR + P + FT + MS + LL + MW + AMSL) \tag{2}$$

7.3. Impact of search and rescue operation cost

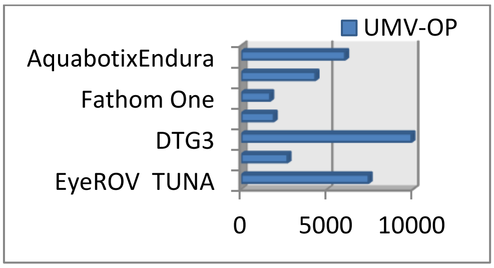
In general, the Sea King contains six flexible bag fuel tanks that hold 3,700 liters of fuel, which gives the helicopter a range of 1,500 km and 1750 km for long-range operation. We calculate the operation cost at 170 INR per litre of white fuel. So, for every 1500 km, the total operating cost is 629,000 INR, or 419.30 INR/km. However, the Syma X8 Pro operates at a very low cost; it requires only electricity to charge its 7.4 V/2000 m Li-ion battery for an hour, costing less than 5 INR per hour. Instead of spending a significant amount of money on helicopters for SAR operations, the use of SAR UAVs is a viable option for conducting SAR operations in the study area for floods and boat capsizes. For SAR operations, more UAVs and UWVs can be deployed at different locations at once, reducing rescue time. Applying CNN for object recognition can yield instant results. The use of UAVs and UWVs is simple and fast, but it depends on the climatic conditions of the rescue location. If the climatic conditions are not favorable to flying UAVs, it is better to opt for choppers.

Table 2. Performance analysis of the UAV

S.No	Name of the UAV	FR (kmph)	P (kg)	FT (minutes)	MS (kmph)	MW (kmph)	AMSL (meters)
1	DJI Phantom-MAVIC 2	5	1	31	72	29	6000
2	YUNEEC-H520 Hexacopter	1.6	0.5	28	61.1551	24.14	500
3	Microdrones MD4-1000	40	1.2	45	43.2	44.2	1000
4	DSLRProsMatrice 210 RTK V2	8	2.31	38	64.37	27	3000
5	AltiGator'sXena Drone	1.3	2	37	45	12	140
6	Syma X8 Pro	0.2	0.30	9	22.54	9	70



(a)



(b)

Figure 5. Overall performance of; (a) overall performance of UAV (UAV-OP) and (b) overal performance of UMV (UMV-OP)

7.4. Discussion

This assessment is distinctive in that it focuses on the real-time performances of both aerial and marine vehicles (UAV and UMV), specifically in the context of SAR flood operations. Most researchers concentrate on internal issues related to aerial operations, specifically the identification of land objects using CNN, including humans and vehicles [22], [23]. Other research is primarily concerned with communication and deployment, path planning, collision avoidance, agile movement, energy efficiency, global navigation satellite systems, and operations in tight spaces [24]-[28]. The integration of both UAV and UMV real-time capabilities is exceedingly uncommon in the field of drone research. The flood-specific synthetic aperture radar (SAR) drones have limited capabilities, but they assist the local administration in selecting the appropriate drone for a given disaster occurrence. Furthermore, the suggested study introduces a novel approach to conducting a cost-effective analysis in real-time for flood and capsize operations, as opposed to sea-king helicopters. Wang *et al* [54]. focused only on the battery performance of the drones and did not discuss any DR and their performance. The current study focuses on other performance parameters like payload, flight radius, and wind resistance, and also discusses UAV and UMV. Zamanian *et al.* [55] also emphasized only energy storage devices with no discussion of drone capabilities. The proposed study is novel and verifies the individual capabilities of the DR. Furthermore, the present study is limited in its ability to estimate DR's capabilities on sunny days. In general, DR performs differently when compared to sunny days.

8. CONCLUSION

This research primarily discusses the optimal method for selecting SAR-assisted disaster robots. This study primarily focuses on two types of surveys: UMVs and UAVs for flood relief missions. The performance examinations of each UMV include EyeROV TUNA, Saif Seas, iBubble, DTG3, Trident, Fathom One, and SEAOTTER-2. Out of the 8 underwater marine vehicles (UMV), the DTG3 has an exceptionally high image resolution of 4K. Additionally, it has an impressive flying time of 480 minutes and a range of 800, making it ideal for underwater SAR operations. A recent assessment evaluated the performance of five UAVs, including the Microdrones MD4-1000. This UAV demonstrated a remarkable wind resistance capacity of 44.2 kmph and a flying time of 45 minutes. These two parameters are crucial for conducting rescue missions in adverse weather circumstances, such as floods. Furthermore, the cost analysis of the SAR operation for the Sea King helicopter reveals that it amounts to 629,000 INR for every 1500 km, resulting in an average cost of 419.30 INR per kilometer. Nevertheless, the operational expenses of the Syma X8 Pro are remarkably low. It only needs electricity to charge its 7.4 V/2000 m Li-ion battery for one hour, costing less than 5 INR per hour. It is depending on the specific location and circumstances; we recommend UAVs as the most suitable choice for SAR flood operations. In flood zones, we suggest using Syma X8 Pro type DR when it's not raining. This study solely examined official flood zones. In really bad disasters with a lot of rain and wind, the results may be different.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

The drone image data is collected from various online resources such as; i) EyeROV TUNA Under Water Drone (source: https://www.eyerov.com), ii) Saif Sea rescue drone (source: https://saifseas.com/), iii) DTG3 Under Water Drone (source: https://www.deeptrekker.com/), and iv) DJI Phantom-MAVIC 2SAR UAV (source: https://www.dji.com/).

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