A Review on Marine Search and Rescue Operations Using Unmanned Aerial Vehicles

S. P. Yeong, L. M. King, S. S. Dol

Abstract**—**There have been rigorous research and development of unmanned aerial vehicles in the field of search and rescue (SAR) operation recently. UAVs reduce unnecessary human risks while assisting rescue efforts through aerial imagery, topographic mapping and emergency delivery. The application of UAVs in offshore and nearshore marine SAR missions is discussed in this paper. Projects that integrate UAV technology into their systems are introduced to highlight the great advantages and capabilities of UAVs. Scenarios where UAVs could provide invaluable assistance are also suggested.

Keywords**—**Marine SAR, nearshore, offshore, search and rescue, UAS, UAV.

I. Introduction

An Unmanned Aerial Vehicle (UAV) is a type of aircraft that does not require human pilot on board. Also known as a drone amongst the general public, it can fly autonomously based on a pre-programmed flight path or remotely controlled by a pilot from a ground station to execute an assigned mission. Due to its potentially autonomous behaviour, the involvement of a human operator is minimized. UAVs can also perform a wide range of tasks that humans might consider as dirty, dull or dangerous to them, for instance, the search phase of a SAR mission in the aftermath of a natural disaster.

The main purpose of a SAR operation is to identify and rescue the target in the shortest possible time. This is critical as any delay will possibly reduce the chances of survival of the victims [14]. Due to their advantages in agility, portability and aerial access, UAVs have already been deployed for SAR operations for a number of years. A recent survey showed that 88 percent of civilians accepted UAVs for use in SAR missions [1]. By mounting a high resolution camera on a UAV, it can provide needed aerial imagery for these missions much more cost effectively than adopting the conventional manned aircraft approach. UAVs can also cover large search areas in a shorter period of time and provide access to remote or difficult to reach locations [13]. In general, these flying robots can monitor the situation from the air using various sensors and devices, then forward the collected information to the human operators at the ground station for further action [23]. Moreover, it is important to understand that the lives of the rescue team could be in risk as well while they are conducting the SAR operations. With the introduction of unmanned SAR systems, many processes will be much safer and faster [3].

Generally, UAVs can be categorized as either fixed wing or rotary wing vehicles. Fixed wing UAVs normally have a longer flight time and are capable of traveling long distances whereas rotary wing UAVs can hover for quite some time and requires only a small area for vertical take-off and landing (VTOL) [16]. Although multiple UAV systems are available commercially, there has not yet been any universal classification to systematically describe models. For instance, Kückelhaus classified UAV based on the build types and included an additional two UAV categories as shown in Table I [8].

TABLE I
STRENGTH AND WEAKNESS OF DIFFERENT UAV BUILD TYPES [8]

	Advantage	Disadvantage
Fixed – wing	• Long range • Endurance	• Poor manoeuvrability compared to VTOL • Horizontal take-off, requiring substantial space
Tilt- Wing	• Combination of fixed-wing and VTOL advantages	• Technologically complex • Expensive
Unmanned Helicopter	• VTOL • Good manoeuvrability • High payloads possible	• Expensive • Comparably high maintenance requirements
Multicopter	• VTOL • Affordable cost • Easy to launch • Light weight	• Limited payloads • Vulnerable to wind due to low weight

This paper reviews the application of UAVs in marine SAR operations both offshore and nearshore.

II. Offshore Marine SAR Operations

According to Ryan and Hedrick, the U.S. Coast Guard uses fixed-wing UAVs with on-board cameras to assist manned helicopters in marine SAR missions [18] as they prevent needless human risk and increase the search area with minimal cost. To integrate UAV into current SAR flight patterns, the UAVs can be controlled to track helicopter maneuvers using specially-designed algorithms while maintaining the desired ground coverage. An expert guidance system for UAVs marine rescue missions is also proposed using Artificial Neuronal Networks [4].

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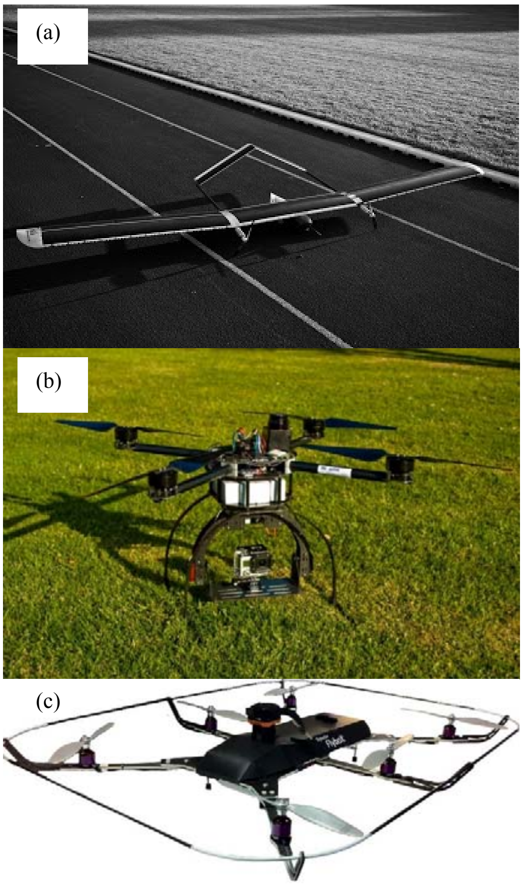

Fig. 1 UAVs in ICARUS UAS platform [3] (a) senseSoar solar airplane by ETH; (b) Quadrotor by ASCAMM; (c) Indoor multicopter – Flybox by SkyBotiX [5]

In Belgium, the Royal Military Academy has developed a project known as the Integrated Components for Assisted Rescue and Unmanned Search (ICARUS) operations which provides robotic support for marine SAR operations apart from urban SAR. ICARUS consists of UAVs, ground robots (unmanned ground vehicles) and marine robots (unmanned surface vehicles) to detect, locate, and rescue humans. Working together in the marine environment, the UAVs are responsible for detecting and tracking victims while the unmanned surface vehicles provide physical assistance to victims to increase their chances of survival [3]. De Cubber stated that UAVs generally could provide topographic mapping and assist SAR operators in being more situation aware and plan missions accordingly [2]. UAVs can also be utilized to track and follow a moving target using a special camera and program that incorporates victim detection algorithms. If SAR teams cannot reach the victims in time, UAVs can provide emergency delivery of lightweight goods such as first-aid kits to victims or SAR personnel quickly. Moreover, they can function as communication relays when a ground communication network cannot be established, especially in remote areas. To fulfil the above requirements, ICARUS unmanned aerial system (UAS) includes the use of three different UAVs: a small long-endurance solar airplane (fixed-wing UAV), a large quadrotor, and a smaller indoor multicopter as depicted in **Error! Reference source not found.** [3].

The safety of rescue teams is a top priority during marine SAR missions and often rescuers are forced to halt or postpone operations due to unfavourable conditions such as extremely poor visibility in adverse weather or wickedly strong currents in water rescues involving divers. Yet, time is of the essence in rescue operations [14] such as a person going overboard. Kurowski and Lampe state this as one of the worst type of accidents. The fatality rate for this type of accident is very high for several reasons. First, the conventional saving approach of the return manoeuvre of the ship, with the subsequent release of rescue vessels, followed by the actual rescue operations consumes too much time. Second, the overboard person may not be able to stay afloat long enough to be rescued due to exhaustion or hypothermia. Last, crews or family members on the vessel often fail to notice the person is missing until it is too late [9].

Several research have been done to save the person who gone overboard. One of the most promising approaches is a complex SAR system prototype called Autonomous Galileo-supported Person rescue at Sea (AGaPaS) developed by multiple research groups from the University of Rostock in Germany. Being a satellite- guided SAR system, AGaPaS aims to act immediately upon incident to reduce the rescue time factor. The target group for AGaPaS are the crews working on special ships or offshore platforms as the system requires crew members to wear a modified rescue vest to detect and locate the person when an overboard accident occurs. An Automatic Identification System emergency transmitter which is self-activated upon contact with seawater is attached to the life vest along with a GPS signal indicator to determine the person's position. Once the emergency message is received, an unmanned surface vessel is released from the ship and immediately moves autonomously towards the overboard crew member and rescues him [9]. By introducing UAV into the equation, the AGaPaS system could be further improved. However, weather conditions such as strong winds or rain, obviously will impact use of UAV in marine SAR operations.

Fig. 2 A major platform fire [17]

Beside overboard accidents, UAVs can also be applied to the emergency rescue system for offshore platform such as when there is a major fire event as shown in Fig. 2. Last year, a fire occurred at Bekok C platform, operated by PETRONAS Carigali Sdn. Bhd. 200km off Terrengganu, Malaysia, during the night. Luckily all 108 workers were evacuated to nearby platforms in time with only six injured [15]. The cause of the fire was suspected to be the sparks from a maintenance valve - an extremely dangerous situation for an oil and gas platform. If some of the rig workers had been panic-stricken and jumped off the platform into the sea, a UAV could be send to locate them or even provide an emergency flotation device that could keep them afloat until rescue arrived.

III. Nearshore Marine SAR Operations

With the current technology development, the typical flight time of a battery-powered UAV is usually around 30 minutes or less, depending on the battery capacity. Therefore, it is difficult to deploy UAVs especially the multi-rotor in emergency incidents that occurs too far away from shore. However, this type of UAVs could be very useful for nearshore marine SAR operations. The concept of providing emergency flotation devices to victims in the water has been piloted by RTS Ideas to save the lives of drowning people nearshore. An aerial rescue robot, *Pars*, as shown in **Error! Reference source not found.**3, was developed by the Iranian lab to save distressed swimmers near the shore.

Fig. 3 *Pars* robot developed by RTS Ideas in Iran [18]

The UAS can be operated by lifeguards or rescue team members via radio control. This eight-rotor machine flies to the victim carrying life rings and drops them to the victim in distress in the sea. The selling point of this drone is its speed. In a trial experiment where it raced against a human lifeguard, *Pars* managed to launch a float to the target victim located 75m from the shore in 22 seconds, while the lifeguard took 90 seconds to reach the person [10], [11]. With an on-board camera, *Pars* can locate the victim's position to release the emergency floating device at the right place. By clinging to the life rings, the victim can stay afloat and this provides more time for the person to wait for rescue. Capable to carry three life buoys in a single flight, *Pars* can save up to three lives at a time. This is especially helpful when there is only a single lifeguard to save multiple people [18]. The first shipment of *Pars* robots which cost up to $10,000 each, will be in mid-2015 [10].

Another entrepreneurial endeavour is the *Ryptide* project. Initiated by Bill Piedra in January 2014, the project also focuses on carrying life-rings in air to rescue distressed swimmers. Unlike Pars, *Ryptide* is actually a piece of equipment designated to be installed onto UAV to carry an inflatable life-ring. After the drone reaches above the swimmer, the deflated life-ring is released and self-inflates as it hits the water [21].

Two PhD students have won a top prize at the Innovation Works! student prototype competition organized by Australian Institute of Innovative Materials and Global Challenges Program, for an octocopter that helps rescue distress swimmers [22]. The drone carries a floating device using magnets. It is then released by remote control to the swimmers in distress. This provides the lifeguards a safer alternative to assist the swimmer in time. It lowers the risk of lifeguards rushing their way through rough sea condition just to reach the swimmer as soon as possible and putting their own life at high risk. A similar invention but with night vision capabilities was developed by students of Ajman University in association with Microsoft, as shown in Fig. 4.

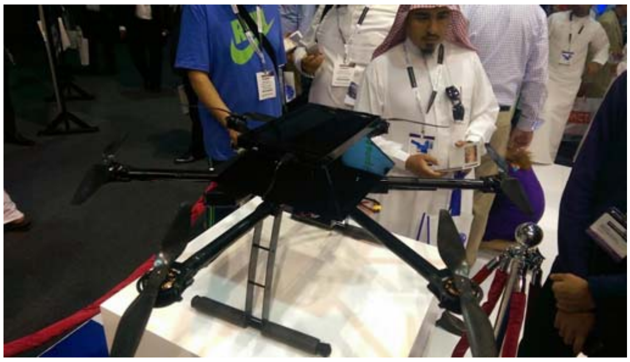

Fig. 4 The UAV, equipped with a Kinect and a Surface Pro device, will not only carry a tube but be able to detect individuals in distress and deliver the tube [6]

Fig. 5 The fatal ferry disaster in South Korea in April 2014 [12]

The concept of delivering floats to distressed victims in the water has received great support from the research or project groups such as those mentioned above to be rapidly integrated into the UAV technology. Life buoy delivering UAVs could have save hundreds of lives during the fatal South Korea ferry disaster in April 2014 if the ferry or the rescue vessels were equipped with such UAVs. The sinking ferry is shown in Fig. 5. Among the 476 people on board, almost 300 people drowned with most of them being Danwon High School students. Some survivors claimed that they had not received any help from the ferry crews which abandoned the ship when there were still hundreds of passengers trapped inside [20]. The ferry also tilted at an angle that caused lifeboats on board unreachable for the passengers as it listed and started to sink [7]. With autonomous UAVs, additional life buoys could have been provided on scene during the critical moments for the passengers to cling to and wait for rescue. It would have provided an alternative to crew directed instructions and given more passengers a chance of survival.

IV. Conclusion

UAVs can be served as a valuable emergency life-saving technology to save more lives while racing against time in offshore and nearshore SAR operations. UAVs reduce unnecessary human risks during rescue operation in adverse weather and are capable of finding victims quickly. Researchers around the world have come up with practical technologies incorporating UAVs to save lives, especially nearshore and in man overboard situations. This research should be furthered and expanded. The authors argue that the civil integration of UAS SAR activities should happen as soon as possible to save lives.

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