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Robotics for Disaster Warning and Response in the UAE

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Abstract: Over the past decade, robot systems have become more commonplace and increasingly autonomous. In recent years, first responders have started to use novel technologies at the scene of disasters in order to save more lives. Technologies are also used for early warning, surveillance and to enhance disaster response capabilities. Increasingly, technologies like robots are used for warning people, monitoring compliance, SAR (Search and Rescue), damage assessment, to search disaster sites. In the case of emergency situations, emergency guidance robots are sent inside of buildings or deployed to search for victims, guide evacuees to safety and other unsafe response tasks. This paper explores the application of robotics for disaster warning and response, benefits and factors influencing deployment of robots, in order to justify the effective usage of robotics for disaster management in the UAE (United Arab Emirates). A pilot study is conducted to achieve this aim, with 24 participants selected through random sampling from three emergency organizations in the country. To increase knowledge and usage of robotics for future disaster warning and response in UAE, it is needful to continue to highlight the role of robotics deployment in helping to minimize risks and disaster impacts on first responders and the public.

Key words: Robotics, early warning, disaster response, SAR, UAE.

1. Introduction

The severity of a disaster sometimes makes it too dangerous or logistically complex to send in human first responders. In these situations, rescue robots can help first responders rescue survivors and accomplish dangerous or complex tasks at a safe distance from hazardous situations [1]. The use of automation and robotics to minimize the risk of disasters is now an area of interest to both researchers and practitioners as disasters continue to occur with increased frequency with high human, structural and economic losses around the world [2]. In several disaster cases, high risk of exposure to hazard usually influence the use of robotics as done during the 2011 disaster at the Fukushima Daiichi Nuclear Power Plant. Complex disasters as that of Fukushima, and natural disasters such as earthquakes, tsunami, volcanic eruption to mention a few, all require logistics of getting people, equipment to affected population [3]. Disaster response also requires safe and effective operations to ensure safety of all responders involved. Though the use of robotics during disaster response in Fukushima has highlighted the promising future of robotics in SAR (Search and Rescue) [4], it also highlighted the shortcomings of robots. Such shortcomings are either due to escalating situations, evolving risk or complex disaster environment [5], all of which have motivated improvement of robotic technologies, and its extended application for disaster prevention where possible, early warning, rescue and or recovery efforts. As noticed in recent times, robots are either replacing humans or working with humans in high risk interventions while ensuring operational efficiency, safety and security of humans [6]. However, some responders are not always aware of these highly effective technological tools or at times have limited knowledge of how best to maximize their use for their agency and for public safety.

A robot is a machine designed to execute one or more tasks repeatedly, with speed and precision [6]. Due to the characteristics of robots, immediate disaster response scenarios are a particularly relevant target for applying such technologies [7]. Robots have

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been used to identify extent of damage and impacts, identify signs of life within debris and assess the safety of buildings before sending people in [2]. There have been resourceful applications of robots in more highly volatile situations such as to scan areas for explosive devices, disarming armed suspect or enemy combatant [8]. Robots have also been deployed into nuclear reactors to assess damages or to gather location information and status of survivors, stability of the structures and rescue victims following disasters [2]. In the last few decades, rescue robots that can fly, swim, crawl through rubble, douse fires or tackle other rescue challenges have advanced tremendously [9]. The uses and application of robotics are exhaustive, and factors that influence their deployment are further examined in this paper.

This paper examines disaster robotics and their applications to manage different disaster situations around the world. The role of robots in conducting early warning and monitoring as well as in SAR provides new avenues for effective utilization of automation and robotics through the mapping of best practices. The paper introduces brief descriptions of selected rescue robotics projects associated with ground, air and sea rescue operations. Applications of automation and robotics during disaster to navigate risky and difficult rescue missions are analyzed based on existing papers and documents. An in-depth review of the 2011 disaster at the Fukushima Daiichi Nuclear Power Plant and COVID-19 pandemic is done to establish the role of robotics in disaster warning and response. This premise is further tested in the UAE (United Arab Emirate) to ascertain the appetite for the use of robots for disaster warning and response. Factors that influence the application and deployment of robots for warning and response are also investigated.

2. Warning and Response Robotics

The most important concern in disaster management is how to warn the public ahead of a disruptive event, and how to preserve human lives during a disaster. The lead time to the onset of any disaster can prove significant, making the difference between life and death. Warning being the process for generating maximally accurate information about possible future harm and for ensuring information reaches people that may be at risk [10] is vital to effective response. The elements of early warning facilitate functionality and effectiveness of warning and response [11]. Ability to effectively communicate the potential harm of a disaster ahead of its landfall, and the use of appropriate tools may be critical to preventing or minimizing the loss of life.

This makes early warning as well as the first 72 h after the disaster the most critical period for SAR operations [12]. The critical elements of early warning such as risk knowledge and monitoring can be undertaken with the use of robotics especially in high risk disaster like pandemic. However, current and past events that show the vast spread and impact of disasters expose that robotics are underutilized for warning. Warning dissemination and communication as well as response capability are important for the major steps in response [13] especially SAR.

The major steps in SAR are to establish the search area, establishing a command point in the search area, dividing first responders into scouts and rescuers and ensuring that scout teams report their findings to the command post and rescuers gather the information from the command post in order to know where to act [14]. According to Murphy, rescue robots can be classified into four major types: UGVs (Unmanned Ground Vehicles); USVs (Unmanned Surface Vehicles) which float on water; UUVs (Unmanned Underwater Vehicles) and UAVs (Unmanned Aerial Vehicles) [15]. Some of the notable applications of robotics in warning and SAR operations are further examined in this study.

3. Application of Robotics for Warning and SAR

The application of robotics for warning is becoming more prominent around the world. They are often used to improve response capability, drones and UAVs have been used for navigation, to record and send details to remote crews [16]. Such warning information can be accessed and communicated to SAR crew and the public as deem fit. In warning context, information by manned and unmanned equipment can provide thermal imaging to help spot risk, temperature level in people and identify survivors [6]. Beyond their use in surveillance, UAVs have also been used to provide lifesaving supplies across some of the most remote regions of the world. Zipline is one of the most well-known, operating primarily in Rwanda and Tanzania. The Zipline company though based in California, USA hires local operators and provides over 11 million people with instant access to medical supplies. Since 2014, Zipline has completed almost 13,000 life-saving drone deliveries including vaccines, HIV (Human Immunodeficiency Virus) medications and blood supplies faster than ground-based supply transport [13].

One of the main advantages of robots is that they can increase the situational awareness of SAR teams by providing better insights of disaster scenes. Robots are capable of using views which humans find nearly impossible, impractical or very unsafe [9]. One example is the Japanese ImPACT project. The ImPACT Tough Robotics Challenge, a national project of Japan Cabinet Office developed robots for disaster response, recovery and preparedness between 2014-2018 [7]. Robots developed include UAVs, construction robots, serpentine robots, legged robots, cyber rescue canine, and several component technologies. During the 2017 Northern Kyushu Heavy Rain caused 36 fatalities and damaged 750 houses, the ImPACT-TRC used a unit of UAVs to gather images of the damaged area. Along a valley 3 km long at 60 km/h without visibility, the robot successfully captured high-resolution ground images of 1 cm/pixel. Images and captured data were provided to the Fire and Disaster Management Agency and the National Research Institute for Earth Science and Disaster Resilience to guide the disaster response. An Active Scope Camera, a serpentine robot prototype was also used to investigate narrow gaps in debris at the Fukushima-Daiichi Nuclear Power Plant from December 2016 to February 2017. The robot effectively captured images of roof structures, a fuel handling machine, and other damaged equipment which led to their decommissioning. The robots provided data and information which were previously unknown [7].

A rescue robot is a robot that has been designed for the purpose of rescuing people or facilitating rescue missions which can be in several modes, shapes or formats. For instance, robotic water rescue system, which is a four-foot, 25-pound remote-controlled robot, used as a hybrid flotation buoy-lifeboat called the EMILY (Emergency Integrated Lifesaving Lanyard) was co-developed by the U.S. Office of Naval Research, and Hydronalix an Arizona based company [17]. In 2016, during the European migrant crisis, the robot was used to rescue hundreds of asylum seekers off the coast of Greece. Reports indicate that EMILY aided more than 240 refugees in its first 10 days of deployment alone. EMILY can cruise at speeds of up to 22 mph (Mile Per Hour) and carry up to five people. It also has a Kevlar-reinforced hull that helps it withstand massive waves and other types of impact [15].

The benefit of robotics usage in disaster warming and response continues to evolve. Over the years, the application of robots is seen to help minimize risks to SAR team as seen in mine rescue robots. Few successful mine rescues with robots are available in literature. One example is the coal mine rescue robot used after the gas explosion accident at the Parker River Mine in New Zealand on November 19, 2010 [16]. Three robots were deployed following the accident, but they were all destroyed following a second explosion. A few months after, the Western Australia Water Service Company succeeded in getting video data of the mine's roadway, to help the police to determine whether the mine can enter the recovery stage [17].

Rescue missions such as this, emphasize the importance and role of robotics for disaster warning and response. The case of Fukushima Daiichi Nuclear Disaster is another example of application of robotics for disaster management. The nuclear accident at the Fukushima Daiichi Nuclear Power Plant in Ōkuma, Fukushima Prefecture of Japan is the most serious nuclear accident since the 1986 Chernobyl disaster and the only other disaster to be given the Level 7 event classification of the International Nuclear Event Scale [18]. The accident was triggered by the earthquake and tsunami that happened on Friday, 11 March 2011 that damaged or destroyed more than one million buildings and led to the evacuation of 470,000 people.

The earthquake and tsunami led to three nuclear meltdowns in the Fukushima nuclear power plant which resulted in airborne radioactive contamination from the damaged reactors and large amounts of water contaminated with radioactive isotopes being released into the Pacific Ocean [18]. In order to reduce radiation exposure, robots were deployed for emergency response and decommissioning of the plants. Applications of robotics such as this make the use of robotics for disaster warning and response an integral part of, and inevitable for effective disaster management.

Successful applications of robotics for warming and response highlight the potential and promising use of robotics in the field of disaster management. Rescue robots can reduce personnel requirements, reduce fatigue, and increase access to otherwise unreachable areas thereby expediting rescue efforts. However, like any technology, there are challenges, robots can self-overwhelm with too much data and they are not always able to adapt to situations different from the test environment in which they were developed [19]. After the earthquakes in Haiti and Japan, the European Commission confirmed that is still a large gap between laboratory conditions in which robots are developed and the use of such technology in SAR operations and crisis management [6]. Rescue robots used in the search for victims and survivors after the September 11 attacks in New York also had trouble working in the rubble and were constantly getting stuck or broken [19]. These challenges allure to limited understanding of robotics and low risk knowledge of robotics application, lack of planning and clarity of roles of SAR team in the use of robots. This influenced the pilot investigation undertaking in the UAE to determine knowledge level and factors influencing application of robotics for disaster warning and response.

4. Methods

Mexico Primary data were collected through quantitative methods in the UAE. The questionnaire was designed to examine knowledge level and factors influencing application of robotics for disaster warning and response in the UAE. A random sampling technique is used to select participants [20] from ADP (Abu Dhabi Police), Emirates Fire and Rescue Company and NCEMA (National Emergency, Crisis and Disaster Management Authority). A total of 24 person participated in this pilot. Data gathered to determine knowledge level and factors were analyzed using SPSS (Statistical Package for the Social Sciences) software version 16.

5. Findings and Discussion

Findings from the pilot study revealed that knowledge level and influencing factors vary. Twenty-five percent (25%) of the respondents are aware of the use of robotics for different aspects of response. Ten percent (10%) indicated that knowledge of robotics application for disaster warning and response is limited. Another 10% confirmed that legal framework, standards and policy are unclear on application and scope of robot usage in warming stage.

In terms of factors influencing robot application, 25% attributed this to resource adequacy, while 30% revealed that clarity of roles and responsibilities limit their use of robots for disaster warning and response. It was further revealed that while regular monitoring is done during disasters, robots are scarcely used. Rather than use robots, established hazard warning systems which are used to communicate with different partner agencies and the public are used. Twenty-four percent (24%) identified training and exercise, 40% identified risk assessment and risk of integrating robotic plan with other agencies as other factors that limit the use, and application of robotics to disaster warning and response.

The findings indicate that there is limited understanding, and use of robots for warning and response in UAE. The findings also allured to limited knowledge of the benefits of robots to the SAR team, emergency organizations such as the ones sampled in the UAE, as well as to the public. Application of robots is not only beneficial to the SAR team but also community at risk. The robots, which were developed by the Japan Atomic Energy Research Institute (now called Japan Atomic Energy Agency: JAEA), were installed or stored in containers for easy transportation to the accident site. Some of the robots were equipped with laser range finder to increase operability.

However, the wide extent of the rubble in the reactor buildings limited the robots. JAEA needed to repeatedly modify the robots to increase portability, and this eventually led to the development of the "utilization policy for emergency response robot system" [21]. It was only in 2017 that the TEPCO (Tokyo's Electric Power Company) successfully used one of its own robots to examine the fuel of the reactor. The process was broadcast through the built-in camera. The robot was also able to retrieve small chunks of radioactive fuel at five of the six test sites, offering tremendous promise for long-term plans to clean up the still-deadly interior [21]. A simulation conducted on safe deployment of robots found that efficient and safe deployment of disaster response robots is possible in phenomenon such as rain, fire and smoke [22].

Undertaking this process shows that exercise through simulation can reduce the required cost and time for each of the stages and the complete process of robotic deployment (see Table 1). This deployment of robot proved critical to response operations with the firefighting robots in France. Colossus, a fire fighting robot, was developed by Shark Robotics of La Rochelle, France and used in the response to the fire that devastated France's Notre-Dame Cathedral earlier in 2019 [23]. The 1,100-pound fireproof robot can blast 660 gallons of water per minute, haul firefighting equipment, transport wounded victims and trigger a 360-degree, high-definition thermal camera to assess a scene [23]. It was summoned by Paris Fire Brigade commander Jean-Claude Gallet when conditions proved too dangerous for the firefighters. Similarly, the Indago drone, was also used in Australia to help battle fires [24]. Such evidences of successful deployment of robots are associated with an in-depth understanding that robot design needs to adhere to a process that is tested and a workplan that is well communicated to all responders [22]. As a result, there is clarity of roles and responsibilities, helping to address one of the factors identified by the study

Table 1 Stages of development and deployment of disaster response robots [22].

Stages	Development/deployment	Actions
One	Robot design	Reduce protyping cost and time
Two	Controller development	Simulate robot development
Three	Operation training	Prevent robot from damage by novice operators
	Workplan validation	Define characteristics of mission, environment to reduce failure
Four	Deployment	

participants as limiting factor to application of robotics for warning and response in the UAE. The finding is a motivation for promoting the role of robotics deployment in helping to minimize risks and disaster impacts on people, infrastructure and systems.

6. Conclusions and Way Forward

As more successes in the use of rescue robots emerge technical challenges are also still present. Regardless, this paper has revealed benefits of robotic for disaster warning and response and the factors that influence limited application of robots in countries like the UAE. With problems associated with information processing of the robot, challenges with the mobility of the robot and the manipulation of the robot, the use of robots continued to be an evolving component of disaster management. Factors such as limited knowledge, resource adequacy, standards and legal framework clarity of roles and responsibilities also need to be addressed in the UAE in order for the country to benefit from the application of robotics. As way forward, it is recommended that further study is conducted to determine the various types of robots used in the UAE, their application, effectiveness and challenges associated with each robotic deployment. UAE emergency organizations would benefit from reviewing the standards of development and deployment of robots in order to ensure they are cost effective, and effective in minimizing risks to lives, as well as successful deployment. The use of robots has the potential to improve disaster management significantly however it should be recognized that real-world use of robots and being able to utilize them in all situations still require some work.

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