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DISASTER CHARACTERISTICS AND IMPACTS ON ROBOTS

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ABSTRACT

Rescue robots serve as extensions of responders into a disaster, providing real-time video and other sensory data about the situation. They are an emerging technology, and have not yet been adopted by the international emergency response community. There have been used in disasters globally, where they were still viewed as a novelty. However, rescue robots are seeing some use in local incidents. For example, several fire rescue departments in Japan and the United States routinely use small underwater robots for water-based search and recovery, a ground robot has been used for a mine explosion in the United States, and interest in the use of aerial vehicles for wilderness search and rescue is growing. The general lack of adoption is to be expected since the technology is new, and the concept of operations of novel technologies as well as the refinement of the hardware and software coevolution will take time. Rescue robot applications are often similar enough to military operations that the same platforms can be adapted; however, some rescue tasks are significantly different than their military counterpart, some tasks are unique to rescue, and the human–robot interaction for civilian response diverges from military patterns of use.

INTRODUCTION

The type of disaster influences the choice of robot platforms and payloads. Natural disasters generally span large geographic areas, making a bird's eye view from a UAV invaluable in establishing situation awareness and determining areas or individuals which need immediate assistance. Manmade disasters are geographically concentrated with the most vital aspects of the disaster invisible beneath the rubble. Small ground robots that can enter deep into the interior of the rubble, and large robots, which can help remove rubble, appear to hold the most promise for manmade disasters. Note the focus on the search for victims and on general information gathering. This focus implies that communications plays a major role in the design of search-and-rescue robot systems and the impact of the environment on wireless communications is an important consideration. Independently of the type of disaster, search and rescue is very demanding both in terms of robotic capabilities and working conditions for the operator. The robot is, by definition, operating in a harsh, mobility challenging environment. The presence of abrasive dust and water, the corrosive effects of wet cement, and the wide range of obstacles in the environment serve to accelerate the wear and tear on a robot; therefore, the adage simple is better is especially true in rescue robotics. The disaster also places demands on the robot operator that will likely impact performance. Certainly, the operator will be stressed by the time criticality and life-saving urgency of the mission. Other sources of stress include: the operator will not be able to keep the robot in line of sight (which is a more favorable operating regime), perception to the robot is computer-mediated and therefore cognitively fatiguing, and the operator is likely to be sleep-deprived and may be at some personal risk.

CATEGORIES AND PHASES OF DISASTERS

An incident may be local or it may be a true disaster; a disaster exceeds local resources or expertise and requires specially trained teams from outside the immediate agency to be involved. Disaster operations consist of four phases: preparedness, prevention, rescue, and recovery. Preparedness and prevention are pre-incident activities,where as rescue and recovery are post-incident tasks. Rescue is also distinct from the recovery phase of a disaster operation; recovery seeks to mitigate longer term threats to life and damage to property and to extract the dead. Rescue is the broad term applied to activities immediately following a critical incident that directly deal with immediate threats to the survivability of those impacted by the event. This includes locating, assessing the medical condition, stabilization, and extrication of survivors. Rescue is often used interchangeably with the term search and rescue, which actually refers to the teams and activities that work in the field, whereas rescue is frequently used by the public to connote the larger disaster management activities needed to support the teams and victims.

Search refers to activities related to finding survivors; while rescue refers to the activities related to extricating survivors. In general, the typical process of search and rescue takes two tracks: strategic and tactical. Strategic operations focus on mission planning and coordination for the entire enterprise, which may involve robots as mobile sensor, communication networks, or logistics support. Within search and rescue, there are numerous specialties and these specialties may impact on the design or use of a robot. Of these, urban search and rescue (abbreviated as US&R or USAR) has been the subject of the majority of work in rescue robotics. Urban search and rescue takes its name from its focus on the aftermath of urban structures collapsing around people. These structures may collapse for natural reasons such as earthquakes, hurricanes, and flooding or they may stem from manmade causes such as structural failures or terrorism. However, there are other types of search and rescue, though these are generally associated with local incidents. Wilderness search and rescue tracks people in the outdoors, such as lost hikers or people buried by avalanches. In order to understand how to apply robotics to disaster response, it is helpful to understand the general pattern of activity, which can be summarized as:

1. Responders become aware of the existence of victims. This awareness may be generated by information from family, neighbors, and colleagues, an understanding of demographic patterns (e.g., at night, apartment buildings will be heavily occupied, while during a work day, office buildings will be occupied), or by a systematic search.
2. The response command staff attempt to understand the disaster site. They investigate the site for conditions such as hazardous materials, the risk posed to the rescuers themselves, any pending threats to trapped victims, and resource restrictions such as barriers to transporting resources to the site, nearby usable equipment and materials that can be exploited, and any other barriers to a timely rescue.
3. The command staff plans the operations.
4. Search and reconnaissance teams are sent to map the situation and assess environmental conditions. Accurate estimates of the need for emergency medical intervention are highly desirable in order to optimize allocation of medication personnel in the field and to prepare ambulances and hospitals.
5. Excavation of rubble to extract victims begins.
6. Responders gain access to victims and apply emergency medicine in situ.
7. Victims are transferred to hospitals.
8. Field teams report activities periodically, usually at the end of the shift, and the command staff modifies or replan accordingly.

Robots are particularly needed for tactical search and rescue, which covers how the field teams actually find, support, and extract survivors. Tactical search and rescue typically begins independently of strategic planning. The first responders on the scene, policemen and firemen, as well as civilians immediately assist with extracting survivors. Regional search-and-rescue teams are deployed and arrive within a few hours, while strategic operations are only beginning to be set up. Based on the condition of the structure and the size of voids, rescuers may enter the rubble, typically using a right-wall-following algorithm. In order to locate inaccessible victims not visible on the surface of rubble, rescuers working in teams of two typically bring in canine teams to smell for the presence of survivors, or use pole-mounted search cameras. Search cameras and boroscopes can usually extend visibility into the rubble by several meters, depending on the irregularity and turns in the voids. If a team has any indication of a survivor, another team is called over to verify the finding. If the finding is verified, and the victim is presumed to be alive, extrication begins. Rescue teams work systematically through a structure and mark each void as to when it was searched and what the findings were.

NATURAL DISASTERS

Natural disasters, such as earthquakes, tsunamis, hurricanes and typhoons, volcanoes, avalanches, landslides, and floods, present many challenges for rescue robots. Natural disasters are usually geographically distributed, perhaps affecting a 200 km or more radius around the epicenter of the event. The sheer size of the affected area presents many challenges to the emergency response.

The primary impact of natural disasters is on residences, light commercial buildings, seawalls and canals, and transportation and communications infrastructure. This means rescuers have thousands of structures to check quickly for survivors, but those structures will be fairly small and amenable to manual and canine search. Besides the sheer volume of structures to check, communication disruptions prevent rescuers from getting timely information as to the state of transportation access and the general needs of an area. However, designing robots to meet these challenges is important because natural disasters provide the most hope of a large number of survivors. Uninjured survivors may simply be stranded and can survive for up to 72 h. Responders are often left with no choice but to break up into small teams and begin searching in the largest centers of population with rescue on a first-come first-served basis. Because of the lack of pervasive communications, these teams and squads must work independently and typically with no real-time access to information being gathered by governmental agencies. Survivors may have hidden themselves in closets or in the attic, and therefore be difficult to detect. The risks to rescuers include live or suddenly re-energized electric lines, gas leaks, contamination from sewage, and victims who may try to protect themselves from perceived looters.

SUITABLE ROBOT TECHNOLOGIESFOR NATURAL DISASTERS

Natural disasters present unique opportunities and problems for robots. The major missions are to provide situational awareness of the distribution and degree of need of survivors (e.g., who needs immediate evacuation, who can remain in place longer), identification of routes of entry for responders, and assessment of conditions that may present a further immediate threat to life. These missions generally require coverage of large areas with information ideally provided immediately to the team of responders. As such, these types of missions favor the use of UAVs, particularly man-portable and man-packable models that can be launched as needed from small clearings and provide real-time video directly to the responders. Rotary-wing UAVs are useful even in densely forested rural areas to Both types of vehicles may be flown at night, but this would be subject to local airspace regulations.

It is important to remember that disasters often have a water-related component. Most of the world’s population lives near a bay or river and relies on bridges and sea walls. USVs are expected to be of more benefit than UUVs in inspecting this infrastructure for several reasons. They can be launched from a distance, and because they provide a view above and below the water line of bridges, sea walls, docks, etc. UUVs are difficult to control in swift water and may become easily trapped by debris in the aftermath of flooding or a cyclonic event. As a whole, ground robots may not be as immediately useful as UAVs and USVs for natural disasters. Ground robots are handicapped by the number of dwellings and light commercial buildings that must be explored at least as rapidly as a human team, compounded by the need to often break down a door or window in order to insert the robot. It is unlikely that ground robots will be able to compete with canines and their ability to smell the presence of survivors without having to break and enter intact dwellings.

MANMADE DISASTERS

In comparison to natural disasters, manmade disasters (such as a terrorist bombing or serious accident) occur in a small area. The challenge is often not how to see the entire external extent of the damage, but rather to see what is not visible: the interior of the rubble, the location and condition of survivors, and the state of potentially dangerous utilities (e.g., electricity, gas lines). The communications and power infrastructure usually exist within a 10 km range and cell phones generally work outside of the collapsed area. Voids in the rubble may be irregular in shape and vertical in orientation. Wireless communications in the interior of the rubble is unpredictable, and generally nonexistent due to the large amount of steel within commercial structures, but the combination of irregular voids and sharp rubble do not favor the use of fiber optic cables. Visibility is difficult as there is no lighting and everything may be covered with layers of gray dust, further hampering recognition of victims, potential hazards, or accurate mapping. The interiors may be wet or contain standing water due to water lines, sewers, and sprinkler systems. Survivors are more likely to be in dire need of medical attention.

SUITABLE ROBOT TECHNOLOGIES FOR MANMADE DISASTERS

The attractiveness of robots for manmade disasters stems from their potential to extend the senses of the responders into the interior of the rubble or through hazardous materials. UGVs are expected to be essential for building collapses, attacks such as the 1995 sarin release in the Tokyo subway, and responses to radiological disasters such as Chernobyl and Three Mile Island, while UAVs are key for mapping external plumes and spills of toxic chemicals. UGVs are expected to be the dominant modality for victim rescue in a building collapse, though other modalities might help with long-term recovery. This strongly suggests that UGVs should be waterproof or at least highly water resistant, since the interior of the rubble is likely to have some water present from the sprinkler and sewage systems. The small size and irregular shape of voids in the rubble also suggests that UAVs, no matter how small, will be unlikely to have enough space to fly in and navigate the interior.

CONCLUSION

Rescue robots are making the transition from an interesting idea to an integral part of emergency response. Aerial and ground robots have captured most of the attention, especially for disaster response, but waterbased vehicles (both surface and underwater) are proving useful as well. Rescue robots present challenges in all major subsystems (mobility, communications, control, sensors, and power) as well as in human–robot interaction. Man-portable and man-packable systems are the most popular because of their reduced logistics burden, but the size of the platforms exacerbates the need for miniaturized sensors and processors.

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