Robots and Humanitarian Interventions: Challenges of Challenging Environments

Key Words: robot, advanced technologies, humanitarian assistance

Asimov's First Law: "A robot may not injure a human being or, through inaction, allow a human being to come to harm."[1]

Abstract
Robots, by being able to work in places and ways humans can't, can make disaster response more effective and less dangerous for responders. However, are robots appropriate for the full range of humanitarian operating environments? The challenge for humanitarian interventions, be they reconstructing a war-torn country, clearing unexploded munitions or doing search and rescue in collapsed building housing garment workers, is twofold: (1) Can robots be effectively managed under extremely challenging operating conditions? and (2) Can robots be deployed at the scale needed to operate in large scale disasters with minimal local support? The paper will explore these two questions in relation to humanitarian interventions to define the challenges faced in using robot and in the challenging environment of humanitarian interventions.

Introduction

Robots and robotics appear to have considerable value-added to disaster relief by saving lives and making the provision of supplies and recovery more effective and efficient at lower risk to survivors and assistance providers. Robots, or a "programmable machine for performing tasks: a mechanical device that can be programmed to carry out instructions and perform complicated asks usually done by people"[2], can replace rescuers in dangerous situations, such as searching collapsed buildings. Small robotic devices can collect aerial images. Large robotic devices can transport supplies or move debris in general and in dangerous locations, such as where unexploded munitions are located.

Robotics, or the "design and use of robots"[3], would thus seem to be a field of considerable potential growth in providing the means to reduce the loss of live and property and improving overall disaster response. At the same time, as with the introduction of any new approach or technology, the conceptual advantages of robots and robotics need to be tempered by consideration for the environment in which these machines will operate. Taking an earthquake in an urban area as an example, is it possible to deploy sufficient rescue robots, with operators and support teams, where they may be no reliable electrical supply and difficult access and hundreds of people reported as trapped, where the window for successful saves is a few days?

The answer is may be yes. But having rescue robots sitting around due to a lack of electricity is a waste of effort. More critically, delivering unusable machines at the expense of other more effective assistance, can costs lives and prolong suffering.

Following a disaster there is a need to ensure that limited resources are focused on the most effective way to save lives and support recovery. To this end, this short paper attempts to answer two questions:

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[1] http://en.wikipedia.org/wiki/Three_Laws_of_Robotics, accessed 23 August 2013.

[2] Bing Dictionary, http://www.bing.com/search?q=what+is+a+robot&pc=MOZI&form=MOZSBR, accessed 23 August 2013.

[3] Bing Dictionary, http://www.bing.com/search?q=what+is+a+robotics&pc=MOZI&form=MOZSBR, accessed 23 August 2013.

1. Can robots be effectively managed under extremely challenging operating conditions?
2. Can robots be deployed at the scale needed to operate in large-scale disasters with minimal local support?

The paper focuses on the use of robots in the period immediately following a disaster where rescue, immediate relief and basic recovery are priorities. These three periods are where robots should be most effective in saving lives and reducing suffering.

Rescue, Relief and Recovery Robots: Characteristics and Uses

Four characteristics define the use of robots in disaster rescue, relief and recovery:

1. **Expendable** – A robot can be destroyed during the course of use, without compromising the overall disaster relief mission. Expendability contrasts with the best practice policy that rescue personnel should not face a reasonable expectation they will be harmed or killed in their work. Being expendable, robots can be put in such situations, as in the case of confined-space searches in unstable collapsed buildings, where they may be damaged or destroyed.
2. **Force Multiplier –** Robots can provide more strength per unit or in more units than the human labor force available after a disaster, particularly for hazardous work. For instance, robots can be built with significant lifting power and designed to cut and remove rubble following an earthquake and work in locations which are considered to be unsafe for humans.
3. **Autonomous –** At least part of the work of the robot can take place without human direct operation. This distinguishes a debris-removal robot from a human-driven front-end loader.
4. **Cost-Appropriate –** The cost of building and operating a robot, taking into account what it is to do, should be appropriate for the benefits gained. A robot which operates in an environment which fatal to humans, will be more cost-appropriate than a single rubble-moving robot which can do the work of 10 workers at the cost of 100 workers, when there are 100 workers are available. Defining cost-appropriate use of a robot is clearly a challenge, if only due to the difficulty of calculating the value of life. But there is no need for Cadillac robots which have little impact because they cost too much to produce sufficient numbers to have an impact.

The ways that robots can be used in disaster rescue relief and recovery operations can be divided into four somewhat overlapping groups related to core tasks:

1. **Data Collection –** This can range from aerial surveillance (e.g., "drones") to robots able to enter environments fatal to humans, to collect data needed to assess needs and manage rescue, relief and recovery.
2. **Physical Manipulation –** This grouping covers a wide range of tasks involving the manipulation of physical items for a specific goal. This can include transport, moving debris and rubble, and clearing and rebuilding roads or other infrastructure, and is probably the most likely area of growth in robot use in rescue, relief and recovery.
3. **Manufacturing –** This group covers robots which produce things needed for rescue, relief and recovery. Such robots, in most cases, will operate distant from a disaster. However, some manufacturing tasks may be best done near a disaster site, such as manufacturing the elements of prefabricated housing or water or road systems.
4. **Labor Saving in Hazardous Environments –** This group largely overlaps with the previous two but focuses on robots working where it is too hazardous for humans to be used directly for physical labor. An example is a demining robot that can work more quickly and with greater reliability than a human deminer, in part because the robot is

expendable and can make mistakes associated with working quickly rather than very carefully.

5. **Precise Actions**– This group focuses on robots which can do tasks where a very high degree of precision is a requirement for successful rescue, relief and recovery. The use of robots for precision surgery can aid a limited number of specialist surgeons in dealing quickly with large numbers injured, for instance due to broken bones following an earthquake. This group may overlap a bit with the previous, as in the case of robots which precisely disarm munitions.

The Operating Environment

The success of a robot in rescue, relief or reconstruction tasks is largely defined by whether the robot is adapted to the environment in which it will operate, defined by the following characteristics:

- **Level of Direct Danger**: Classically, direct danger to a robot comes from being in an environment which is dangerous, e.g., can explode, or under great pressure, e.g., under seas. Robots involved in managing industrial accidents or deep-water search and rescue, would need to be able to operate despite direct danger. However, robots operating in conflict or post-conflict situations could face direct danger from unexploded ordnance, or (like humanitarian workers themselves) physical attack.

  While the use of robot can be justified given their expendability, the cost and effort of deploying robots to a disaster does not make it likely that they shouldbe damaged or destroyed immediately on deployment. Thus, there is a need to make robots operating in direct danger situations to have a significant level of survivability defined by the level of expect danger. While robots can go into environments humans can't safely, it is unlikely that armed protection for robots would be available, in most cases.

- **Climate**: Rescue, relief and recovery robots need to be able to operate under extremes of heat and cold, with the former presenting possible significant challenges in cooling. Robots also need to be physically isolated from, or tolerant of, dust and moisture. While moisture can be expected following flooding, both floods and earthquakes, as well as mass wasting, can general considerable volumes of fine dust which can affect sensors, seals, operating surfaces and internal components. Many climate factors can likely be addressed in the design process, but can also drive up the unit cost of a robot, presenting both cost-benefit and sticker-shock issues.

- **Energy**: In general, post disaster environments are energy-poor. Electrical systems are down, both liquid and gas fuels may not be widely available or may be rationed, and facilities to charge batteries or other sources of energy (e.g., compressed air) are not likely to be available. Of course, the energy sector tends to recover quickly after a disaster but access to supplies can be an issue for some time post-disaster, as in the case where rationing electricity limits access to in-ground fuel stocks.

  The optimum would be for robots to be self-sufficient in energy needs for days or weeks of operation, but this is unlikely in most cases. The second option is for energy supplies to be carried with the teams supporting the robots (see below). However, the challenge here is again cost-to-benefit (e.g., one 100 kg. robot requiring 20 kg of fuel a day) and the logistics needed to provide this energy. Robots working rescue, relief or recovery operations need to use as little energy as possible and many possible robots may be too energy intensive for deployment.

- **Support and Servicing**: A post disaster environment is generally characterized by a lack of resources. The provision of support (e.g., deployment assembly, repairs, redeployment, etc.) and servicing (largely fuel) cannot expect that any of the resources needed for these tasks will be available locally. As a result, support and servicing needs to operate on an autonomous basis, including the support and servicing for those providing the support and servicing to robots. Meeting these double needs can be costly, logistically demanding and compete with the provision of other relief and recovery assistance.

  An added complexity is that not all disasters are resource poor, or can be poor for only some resources (e.g., fuel). A result is that a support and servicing package designed for the worst-case scenario may contain far more resources than typically needed, and at a higher overall cost.

- **Management**: While robots are intended to operate independent of direct human management there is a need to, at least, monitor the work of rescue, relief and recovery robot. More likely, there would be a need to provide updated information, change assignments and modify operating protocols. The work by robots would also need to be managed to ensure they are working on priorities and in locations and ways that support the overall rescue, relief and recovery effort.

  While a level of management can be done from a distance (e.g., via satellite uplink), there also need to on-site management to enable robots to work in collaboration with human rescue, relief and recovery personnel. While it is likely that some level of robot-human interface can be built into robots, it is unlikely that all possible uses of robots can be managed in this fashion. Thus, even where humans and robots can communicate at the work site, there is likely to be a need for on-site management, if only to ensure that groups of humans and groups of robots are working safely together and to a common purpose.

  This on-site management demands additional support and services and needs to be done at a higher level of efficiency than one manager to one robot. The management for local operations can be complex and present significant challenges in development and operation.

Conclusions

This paper has briefly outlines a range of factors to be taken into account in developing and deploying robots for post disaster rescue, relief and recovery. Work is well underway in developing robots that can work in post-disaster environments, for instance through the Defense Applied Research Agency[4] and the work of the Center for Robot-Assisted Search and Rescue[5].

While there is significant potential for robots to save lives, reduce human suffering and hasten recovery, there are also significant challenges to be faces. These include:

- Managing danger, particularly from human-related hazards,
- Ensuring sufficient energy to enable robots to operate for sufficiently long periods to time and at reasonable cost to benefit.

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[4] See http://www.icra2013.org/?page_id=1659.

[5] http://crasar.org/.

- Reducing support and service requirements to reduce costs to benefits as well as the impact of scarce resources (including logistics capacities) needed to support robot operations post disaster.
- Developing effective human-machine management systems to ensure that rescue, relief and recovery operations are effective, coordinated and as efficient and safe as possible.

An additional issue, linked to cost and benefits, is defining when humans or robots are the best option. On the one hand, it is fairly straightforward that deploying robots into environments which are immediately deadly to humans makes sense.

However, a different set of factors need to be considered when faced with deploying a limited number of robots for collapsed building rescue where there are more buildings than robots: Which buildings get robots and which human rescue teams?

For delivering relief supplies or recovery work, does it make sense to deploy robots where there is a large, unemployed labor pool? The humans may be less efficient on a per-unit basis, but greater benefits come from increase employment, economic stimulation and psychological wellbeing when humans are engage for this work.

The point here is that the use of robots for rescue, relief and recovery should not just consider they relative strengths of robots as machines which may be more capable, or expendable, than humans, but how these machines fit into the social structure of disaster rescue, relief and recovery. Certainly, robot can made these efforts more effective and reduce human suffering. But we need to keep in mind that rescue, relief and recovery focus on the disaster survivors and not alone on the means and machines involved in these tasks.

Referring back to the two questions posed at the beginning of the paper:

Can robots be effectively managed under extremely challenging operating conditions?

Most likely, but these management efforts need consider the costs and benefits involved, and the need to interact with humans, both disaster survivors and rescue, relief and recovery personnel.

Can robots be deployed at the scale needed to operate at large scale in a disasters with minimal local support?

The challenges posed particularly by the need for energy, and to a lesser degree by support and service and on-side management, make it difficult to expect that large-scale deployment of robots for rescue, relief and recovery is likely in the near future. Other benefits from using humans for many post disaster tasks, including economic stimulation and psychological health, may mean less efficient humans are preferred over more efficient robots. At the same time, highly specialized robots may find a productive niches, such as aerial surveillance, largely because the tasks involved are relative simple and a single robot can cover most or all of the need at any one time.

Sources

This paper was developed based on experiences from the author's 35 years of work on disaster management and the following sources:

Center for Robot-Assisted Search and Rescue (CRASAR) at Texas A&M University

http://crasar.org/

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