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NEED FOR ROBOTIC SOLUTION FOR HAZARDOUS ENVIRONMENT

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ABSTRACT
Robotics researchers have worked hard to realize a long-awaited vision: machines carrying people from burning buildings or tunneling through collapsed rock falls to reach trapped miners. In this chapter we review progress. Researchers still have many challenges ahead of them but there has been remarkable progress in some areas. Hazardous environments present special challenges for the accomplishment of desired tasks depending on the nature and magnitude of the hazards. Hazards may be present in the form of radiological or toxicity dangers to potential explosions. Technology that specialized engineering companies can develop and sell without active help from researchers marks the frontier of feasibility. Just inside this border lie tele operated robots for explosive ordnance disposal (EOD) and for underwater engineering work. Even with the typical tenfold reduction in manipulation performance imposed by the limits of today's telepresence and teleoperation technology, robots usually offer a more cost effective solution. Most hazardous applications lie far beyond the frontier, although researchers managed to establish some limited inroads by the turn of the 21st century. Fire fighting, rescue operations, removing high-level nuclear contamination, reactor decommissioning, tunneling through rock falls, and most landmine and unexploded ordnance problems still present many unsolved problems.

NEED OF ROBOTICS
Hazardous environments present special challenges for the accomplishment of desired tasks depending on the nature and magnitude of the hazards. Hazards may be present in the form of radiological or toxicity dangers to potential explosions. When the magnitudes of hazards reach the point that human exposure would either represent a direct threat to life or long-term health consequences, some form of remote operations that separate humans from the hazards must be employed. An extensive example of such operations is environments involving nuclear radiation; in fact many of the technical roots of modern robotics technology can be traced back to nuclear remote handling manipulators and support systems. Remote handling and operations concepts using engineered systems that allow humans to work effectively from a safe environment have evolved over the years.

Today, such remotely operated systems are used widely in many areas and recently they have become routinely used in explosives disposal, security operations, and handling of dangerous biological materials. A remote handling system will generally involve subsystems for mobility, manipulation, tooling, sensing, and human–machine interfacing. Nominal operations involve the collective workings of these subsystems to accomplish remote operational goals. Any remote handling systemwill eventually experience some aspect of off-nominal operation that may be the result of unexpected environmental events or system malfunctions. The fundamental idea is to connect the human operator to the remote environment via a power and signal infrastructure that allows effective operation in the remote environment: mechanized devices and sensor systems that allowthe human's perception and action capabilities to be projected into the hazardous environment to perform remote operations.

The more realistic this projection, themore natural and effective the human remote control will be. Because of their inherent complexity and the very nature of remote operations, operator training is a major challenge that requires the use of simulations and cold testing facilities that provide operators with comprehensive and realistic training. Such training will typically encompass all aspects of nominal and anticipated offnominal operations. Remote handling systems themselves will eventually experience equipment failures. Remote maintenance/ operation of failed remote maintenance systems must be an integral part of their basic design and operational features. Hardware/software features must be provided for the analysis of, recovery from, and correction of problems.

Robotics researchers have worked hard to realize a long-awaited vision: machines carrying people from burning buildings or tunneling through collapsed rock falls to reach trapped miners. Technology that specialized engineering companies can develop and sell without active help from researchers marks the frontier of feasibility. Just inside this border lie teleoperated robots for explosive ordnance disposal (EOD) and for underwater engineering work. The necessity for people to wear protective suits in these situations limits their endurance and dexterity. Even with the typical tenfold reduction in manipulation performance imposed by the limits of today's telepresence and teleoperation technology, robots usually offer amore cost-effective solution. It can be left in place overnight or during rough weather. Free-swimming robots are much more complicated and expensive and have to be hauled out of the water when not under active control. Limited autonomy or autonomous operation for a restricted time can relieve operator fatigue and allows unmanned aerial vehicles (UAVs) to fly extended reconnaissance emissions with occasional precision weapon delivery. Such missions would be too hazardous or too politically sensitive for manned aircraft. Most hazardous applications lie far beyond the frontier, although researchers managed to establish some limited inroads by the turn of the 21st century. Fire fighting, rescue operations, removing high-level nuclear contamination, reactor decommissioning, tunneling through rock falls, and most landmine and unexploded ordnance problems still present many unsolved problems.

APPLICATIONS

Applications of robotic systems in hazardous environments encompass an extremely wide spectrum. The solutions for these different environments are equally diverse. In general such applications involve unique challenges associated with the uncertainty and unstructured nature of the associated tasks. In this discussion, two application areas that are very different have been selected to give the reader a deeper sense of technology evolution, accomplishments, and remaining challenges. Landmine eradication, sometimes referred to as demining, is a current application domain with humanitarian importance and extremely difficult and dangerous outdoor conditions.

Eradicating Landmines

Efforts to construct a practical robotic device to help with landmine clearance have met with only limited success. While remote control technology has enabled some existing machines and vehicles to be used in hazardous situations, we are still a long way from achieving reliable robotic mine clearance. It is instructive to understand why many expectations have turned out to be hopelessly optimistic. Landmines, a simple type of victim-activated explosive device, were used extensively in Europe and North Africa during the Second World War between 1939 and 1945. Extensive clearance operations in 1945 and 1946 removed nearly all of the landmines then in use Landmines were used extensively in subsequent decades. Along with antipersonnel cluster bombs, they caused extensive civilian and military casualties in Vietnam and Cambodia from the 1960s onwards. However, it was not until their widespread use in Afghanistan, Angola, Cambodia, and several other countries in the 1980s that they were recognized as a major humanitarian problem. Landmines blocked aid efforts needed to rebuild communities following civil conflicts. The Red Cross and the International Campaign to Ban Landmines (ICBL) successfully promoted a ban on the use of landmines that came into effect in 1997 as the Ottawa Treaty.

The knowledge that thousands of children were losing their legs, even their lives, motivated hundreds of researchers to develop new technologies to help eliminate this threat. By 2000 ICBL estimated that over 80 countries were affected by landmines and other explosive remnants of war such as cluster bombs. Although many countries that have not signed the Ottawa Treaty still have extensive stocks of landmines, the treaty has been effective in restricting the use of landmines as much through peer pressure as enforcement. A few countries and several nonstate actors continue to deploy landmines according to recent reports. However, explosive remnants of war such as cluster bombs and other munitions have become, yet again, an increasing problem in Iraq and Afghanistan. There are several basic types of landmines and unexploded ordnance (UXO) that continue to cause problems in many countries.

Antipersonnel (AP) blast mines, made predominantly of plastic with small metal firing pins and detonator cases, typically contain between 20 g and 100 g of explosive. These mines only cause extensive injurieswhen they detonate within a few centimetres of a person. Typically they lie buried just below the ground surface and are activated when the victim steps on top of the mine. Shattered fragments of bone pass through the flesh of the leg at high velocity. If the victim survives long enough to reach hospital, amputation above or below the knee usually saves his or her life but the victim will need prosthetic legs, replaced at regular intervals. Antipersonnel fragmentation mines contain similar quantities of explosivewith a thick metal case that breaks into high-velocity fragments when the mine explodes just above the ground surface. Older fragmentation mines were mounted on posts; more recent varieties lie buried but jump into the air when activated and explode at waist height, killing or seriously wounding victims up to 200m away. These mines are much easier to detect so they are often protected by nearby antipersonnel blast mines to deter theft. Antivehicle (AV) or antitank mines (AT), made predominantly of plastic with small metal firing pins and detonator cases, are large versions of the AP blast mine and typically contain 5–10 kg of explosive. Some have a thick metal plate on top that can penetrate 50 cm of armor plate on the underside of a tank. These mines cause significant damage even to mine-resistant vehicles which have blast-resistant hulls, offset wheels, and additional protection for occupants. Air-dispersed munitions such as cluster bombs (CBs) were not intended to be victim-activated. Several hundred are released from a single canister and they are designed to explode on impact with the ground. Typically between 5% and 25% failed to explode immediately and lie in a partially triggered state either on or just below the ground surface. Some will detonate in response to electromagnetic fields from metal detectors, and others will detonate with the slightest movement. Most explode like powerful fragmentation mines with a lethal radius of up to 200 m. Improvised explosive devices (IEDs), often in the form of roadside bombs, are increasingly used by insurgent groups fighting organized military forces (asymmetric warfare). They are often made from large UXOs fitted with remote controlled detonators. Ironically the UXO is often unintentionally donated by the same organized military forces who become the targets of these devices. Evolution of Landmine Clearance Techniques

HAZARDOUS MATERIALS HANDLING AND OPERATIONS

The oldest application of robotics-related technology to hazardous environments is various aspects of remote nuclear operations dating back to the beginning of serious work on atomic physics in the early 1940s. This section discusses hazardous materials and operations in the context of nuclear applications and some extrapolations to other domains. These applications run the spectrum from low- to high-fidelity manipulation and multiple mobility modes. Many variations of remote handling systems have been in use since man has attempted to cope with hazardous environments. In the 1940s, research in atomic physics led to a new era in remote handling as scientists sought to explore the nature of materials involving ionizing radiation.

As experiments became more complex, mechanical manipulator systems were created which allowed operators to perform increasingly complex tasks safely behind thick biological shielding. These mechanical systems then evolved into electrical systems that allowed larger work volumes to be considered. Incredible engineering achievement occurred in a 15 year period within the Remote Control Division of the Argonne National Laboratory. Even though this era represented tremendous technical achievement, it went further in illustrating the intrinsic complexity of remote operations. The equivalent work performance achieved with sophisticated teleoperated remote systems is poor in comparison to what human workers can achieve with direct contact operations and common tools. Typically, this form of teleoperation (i. e., manual control over a physical distance or barrier) is ten to hundreds of times slower than conventional contact operations. Remote operations are extremely expensive and time consuming and have been the continual target of engineering improvements over the years. Many research and development efforts have focused on different avenues for improving the work efficiency of teleoperated remote operations. These efforts have included the development of better manipulators, control stations, control algorithms, etc., all intended to enhance reliability and maintainability. In the late 1960s and early 1970s, as digital electronics became more cost effective, interest began to emerge in the integration of automation with teleoperation as a scheme to effectively increase remote operations work efficiency. It was around this time that industrial robot concepts were also introduced. Combining selective automation of specific subtasks with traditional teleoperation offers the potential to reduce labor requirements and to improve the quality of repetitive task executions. This integration of automation with teleoperation became the foundation of what is now termed telerobotics. From the 1970s until today, telerobotics has been an active area of research and development in many different domains that include nuclear, space, and military applications.

SITE CLEAN UP APPLICATIONS

Robotic and remote systems have been used in assessing the status of sites contaminated with hazardous materials. These surveys are essential in planning and executing subsequent clean up operations. Such systems have been used most extensively in nuclear waste sites around the world because remote techniques are more common in many nuclear operations. There has been some use of robotic survey systems in chemical and biological hazard situations as well. Survey Systems. Numerous robotic survey systems have been developed and used. The basic idea is to integrate a sensor suite, appropriate for the contaminants of interest, with a suitable mobile platform that incorporates remote and/or autonomous driving functions and requisite navigation and control functions. The desired output of the survey process is a precise map of contaminant locations and concentrations. Such systems have been developed for both outside and inside operations. It was common practice in many industries for a number of decades to bury hazardouswastes in earthen trenches in isolated burial sites. Usually, useful records of what materials were buried at what locations either did not exist or were not accurate. In fact, the general conditions of such buried waste sites are often unknown to the extent that human entrance is not allowed. As a result, the first step toward remediation is to quantitatively assess the physical and hazard conditions of the site. The robot's location is monitored with Global Positioning System (GPS). The suite of sensors includes eddy-current probes and ground-penetrating radar that reveal density contours, radiation detectors, and gas emissions monitors. This systemwas an initial prototype that could be operated from a remote driving station or operated in autonomous programmed trajectory mode. The system was controlled using a radio communication link. Its unique feature is that it was designed with minimal use of ferromagnetic materials to minimize interference with the magnetic subsurface sensors.

CONCLUSION

If we are to learn anything from the experience of the last decade we must appreciate that robotics research is just one step in the development of tools that extend human capabilities. Researchers need to make significant advances on four different fronts: mechatronics design, sensing, machine intelligence, and problem understanding.. Mechatronics designers have to trade gains in precision, dexterity, mobility, and strength for losses in endurance and reliability. We are mostly well short of biological (e.g., human) capabilities except for high-precision applications. Machines have much the same environmental tolerance as people. Machines need special precautions against heat and cold outside the temperature range of 0–35 ◦C, and operation beyond −60 ◦C or +60 ◦C is usually impractical. Dust, radiation, low or zero air pressure, fumes, biological agents, even insects can be fatal for machines without special design features, which may result in performance reductions. Maintenance or repair work may necessitate decontamination before people can work on the machinery. While electronic sensors can go far beyond biological capabilities, hazardous applications still present problems far beyond present capabilities as we have seen in the case of landmine applications. Radiation levels that are lethal for humans can also quickly kill electronic sensors. Extreme heat or cold limits performance, as can contamination, and even insects

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