Robotic Support for Infectious Disease Crises
A Task Force Proposal

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The recent coronavirus pandemic has highlighted the challenges faced by the healthcare, public safety, and economic systems when confronted with a surge in patients that require intensive treatment and a population that must be quarantined or shelter in place. The most obvious and pressing challenge is taking care of acutely ill patients while managing spread of infection within the care facility, but this is just the tip of the iceberg if we consider what could be done to prepare in advance for future pandemics. More generally, there are a family of events such as this which have the potential to stretch the capacity of the healthcare, public safety, and economic systems to and beyond the breaking point.

The National Academies' Standing Committee on Emerging Infectious Diseases and 21st Century Health Threats[1] established at the request of OSTP has been addressing the problems from the perspective of infectious diseases and public health policy. Our belief is that there is a need for a complementary effort to anticipate and address the engineering challenges associated with pandemic infectious disease emergencies.

There is a substantial role for robotics to fill the gap in capacity for such events, as noted in a recent editorial in *Science Robotics*.[2] However, the roles that robotics may fill will vary depending on context (disease type and burden, deployment location, level of training of healthcare workers, and so forth) and agency or institution (public health departments, hospitals, public safety, home care, etc.) Also, every disaster presents new twists or unforeseen challenges. Thus, any robotic solution must be highly flexible and field programmable so that it can be readily adapted to situations as they arise. Indeed, by developing such healthcare, public safety, and manufacturing and logistics robotics capacity, it would become possible to both improve economic productivity for normal operations, create new jobs and economic opportunities, plus have a national stockpile of these systems that could be deployed as needed to address national needs, whether it be today's pandemic, or a future natural disaster, or some

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1 https://www.nationalacademies.org/our-work/standing-committee-on-emerging-infectious-diseases-and-21st-century-health-threats

2 https://robotics.sciencemag.org/content/5/40/eabb5589

other not yet anticipated healthcare crisis. We see robotic systems as pervasive tools that can permit existing public health, public safety, and infrastructure to scale to the size of a pandemic and reduce deaths, disability, and economic disruption.

Early prototypes of systems that can be used in a healthcare crisis already exist. For example, CloudMind, a Bejing-based company, recently donated several prototype robots to aid in COVID care.[3] While these systems were deployed in response to COVID, in fact they were designed for a broader field of use, illustrating the potential to build general-purpose and quickly retargetable robotic technologies. Many other examples exist, including both pre-existing healthcare support systems (e.g. TUG delivery robots[4]) as well as systems that have been adapted for the current crisis -- e.g. UV-C disinfection robots now being deployed in hospitals around the country.[5]

Potential Contributions of Robotics

Potential uses of robotics include at least six areas: 1) in-patient clinical care; 2) public health uses outside of in-patient care settings; 3) home care support; 4) healthcare laboratory and supply chain automation; 5) continuity of work, government, and quarantine support; and 6) public safety Each of these requires different physical platforms, involves different public, regulatory, or private stakeholders, and emphasizes different aspects of robotics. We discuss ideas related to each briefly below.

Clinical Care: Medical robotics as a field has largely focused on in-patient, high-value interventional care. However, as illustrated by the CloudMind deployment, in cases like the COVID pandemic, many more high-value points emerge. As discussed in the abovementioned *Science Robotics* editorial, robotic systems can also play important roles in clinical care associated with infectious disease which includes both reducing healthcare worker exposure to infectious diseases and providing "hidden" functions of safe waste disposal, decontamination of hospitals and public spaces, delivery of prescriptions and meals. As the editorial states, "areas of specific importance include disease prevention, diagnosis and screening, and patient care and disease management."

In all of these cases, the key observation is that a pandemic disease like COVID introduces a large population of patients who are both highly contagious and very sick. This requires a large amount of direct patient support while ensuring the safety of trained caregivers, which are cannot be rapidly replaced and may have a finite set of protective resources such as masks, gloves, and gowns.Robotics can increase the capacity of the system if it is able to perform some of the patient management functions (for example, decontaminating rooms (which appears to

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[3] https://www.cnbc.com/2020/03/23/video-hospital-in-china-where-covid-19-patients-treated-by-robots.html
[4] https://aethon.com/mobile-robots-for-healthcare/
[5] https://spectrum.ieee.org/automaton/robotics/medical-robots/autonomous-robots-are-helping-kill-coronavirus-in-hospitals

be the most pervasive use of ground robots for clinical applications in China), changing IV bags, managing a ventilator) without requiring a caregiver to move into and out of the room containing the patient. This spares both PPE and time. Likewise, using robots to perform disinfection or cleaning tasks reduces human labor and disease exposure. They can also perform many supply chain functions within healthcare facilities.

Public Health Support: Public health agencies also interact with the population for hospital admissions, managing quarantined citizens, and providing follow up home care and these applications would benefit from advances in robotics. In a crisis, intake into the hospital almost always requires some level of triage and/or testing. This is again skilled labor intensive, and, in the case of infectious disease, creates the potential for disease exposure for both care providers and patients. Robotic systems are ideally suited to perform many of these initial triage functions and can be used outside of point-of-care facilities, reducing possible contamination, and transferred to rural locations where there are few health workers. Robots can take temperature, blood pressure, capture sounds such as coughing and can even perform basic imaging functions (e.g. ultrasound) and sample collection (e.g., nose swabbing, phlebotomy). This can greatly speed testing of large populations while protecting healthcare providers and reducing the depletion of N95 masks and other resources during the identification and triage process.

Home Care: One of the major looming challenges with COVID will be the indirect impacts, particularly in mental health, of the disease for both those who are isolated due to the growing “shelter in place” orders, or because their support network is sheltering in place, or because of loss of employment, etc. For those who have been discharged, there is the need for continued health monitoring. In other healthcare crises, there may be potential for home care, the need for rehabilitation, and so forth. Despite the maturity of the field of networked robotics, there currently are no mature robotic products for telemedicine.

Home care robots, even if teleoperated, will pose new social robotics challenges. The emergence of social robotics, and the growth of HRI in general, in part due to the focus on collaborative robotics within the NRI, highlights the opportunity to deploy post-care support within affected areas.

Healthcare and Laboratory Supply Chain Automation: Robotic systems are being used increasingly in laboratory operations, for example, in running clinical tests, or in manufacturing pharmaceutical drugs and personal protective equipment (PPE). There clearly is a potential to redirect these systems to similar applications in response to an emerging pandemic. In many cases, the ability to fabricate associated fixtures and ancillary equipment and to rapidly reprogram the robots themselves can have a large impact on how quickly these systems can be redeployed. Transportation of infectious samples is an important aspect of laboratory operations, as well as delivery of quarantine materials, and we are seeing the use of delivery robots.

Continuity of Work, Government, and Quarantine Support: Private industry and individuals are economically impacted by infectious diseases in ways that are not typically addressed by the public health and public safety communities. Telecommuting has allowed many workers and officials to shelter in place and education to continue. However, highly automated warehouses are in danger of closing[6] because human workers do play an important role in these warehouses and social distancing policies are not practical. Likewise critical, but routine, services such as electrical power generation and water treatment require humans, as well as setting up emergency shelters and hospitals is a tedious, labor-intensive operation. While China did build a hospital in Wuhan in 10 days[7], it required a massive deployment of human capital and used drones to carry lighting to allow the workers to work at night. Despite the maturity of the field of networked robotics for both healthcare and industry, there currently are no mature robotic products for telework or telemedicine that permit both mobility and manipulation.

Public Safety: Public health, law enforcement, and transportation officials typically work together to maintain public safety overall. At least eight countries are using ground and aerial robots to identify infected individuals in public spaces, decontaminate outdoor public spaces, and to monitor movement of people, either walking or in cars, and enforce quarantines. Ground or aerial robots can move through a distributed population for the purposes of assessment, or as a way to reduce the need for patient movement to centralized locations. In the case of COVID, deploying robots into the population would make it easier to test for disease, particularly in underserved areas. However, roboticized public safety has already generated a backlash in Italy and the UK, highlighting the need for understanding human-robot interaction.

Technology Challenges

Robots intended for public health, public safety, or workspace operations must meet or exceed different standards and regulations, necessitating advances in reliability and decontamination as well as increased functionality.

While opportunities for robotics to support large-scale healthcare crises abound, there are numerous challenges to wide-spread and effective deployment of robotic support systems. These include cost, ease of use, reliability, safety, and disinfection, to name a few. There is a need to assess current capabilities and match those capabilities with potential support roles and routine tasks within the healthcare environment.

Creating scalable systems that can provide these functions is very demanding. Hospitals vary widely in terms of physical layout and the type and placement of equipment. The environments in which public health support and supply chain augmentation take place are even more varied.This becomes even more challenging when emergency treatment units (M*A*S*H style

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6 https://www.wsj.com/articles/amazon-struggles-to-find-its-coronavirus-footing-its-a-time-of-great-stress-11585664987?mod=hp_lead_pos10

7 https://www.businessinsider.com/how-china-managed-build-entirely-new-hospital-in-10-days-2020-2

tents) are used or large public spaces such as the Dallas convention center is repurposed. It is impractical to design and pre-deploy systems that are custom-designed for every possible contingency. However, a judicious mixture including on-hand inventory, standardized, rapidly replicated designs, and plans for adapting the increasingly pervasive installed base of robotic systems could make a big difference in the next crisis.

As highly programmable devices, robotic systems and technology can (in principle) be adapted to function effectively in widely varying environments. Continuing advances in rapid prototyping, sensing, machine vision, and artificial intelligence will further increase this adaptability. The ongoing multi-agency National Robotics Initiative coordinated by the National Science Foundation is accelerating the capabilities of robotic systems to work effectively in unstructured environments. But a greater emphasis must be placed in developing at-scale, robust, and physically dexterous robotic systems that can function at a distance with efficiencies approaching that of human labor.

As the Apollo 13 incident proved, engineers can be extremely inventive in adapting materials on hand to meet a pressing need. Indeed, we are seeing the same sort of innovation in the present crisis, though better coordination could be immediately helpful. However, an infrastructure that promotes rapid sharing and evaluation of improvised solutions, together with the availability of more-or-less standardized hardware designs and software that are accepted by regulatory agencies or institutions that can accept liability for incorporation of innovations, and which can be rapidly replicated and adapted to specific environments, can make the difference between solutions that are helpful in an emergency and those that come online too late to make much difference. This infrastructure must necessarily include enough trained professionals to implement rapid deployment on a large scale.

Similarly, preparing for the next crisis will necessarily require planning and creation (in advance) of partnerships between public agencies (e.g., local and state health departments), hospitals and personal care physicians (which are often privately owned and operated), public safety and transportation agencies, and private industry. Advance consideration should also be given to intellectual property and safety concerns that may arise in a rapid deployment situation.

Statement of Task

We propose that a committee be established to study the potential for robotic systems to assist in healthcare emergencies. This committee should include representatives from the engineering/robotics community, clinicians & critical care workers, public health experts, and emergency responders. It probably should operate under the auspices of, or in coordination with, the existing Standing Committee, but with a specific focus on the role of robotics and related technologies. Some of the possible activities of this committee might include:

- Using the existing COVID-19 emergency, and building on previous experience with the 2014-2016 Ebola outbreak[8], as a focusing example, examine the challenges faced by health care responders and by the general population.
- Examine possible and proposed robotic/technological responses to these challenges, together with any available experience with them.
- Depending on how quickly this can be done, provide a clearing house for promulgating designs or the current crisis.
- Propose a strategy for increasing national preparedness to use robotic systems and technology in future emergencies.
- Identify key research/knowledge barriers that need to be addressed in developing effective, scalable solutions to foreseeable future challenges including the human-robot interaction with systems, especially for public safety or in-home care
- Identify workforce training, regulatory, and infrastructure needs that should be addressed in order to enable rapid deployment of these systems.

[8] https://obamawhitehouse.archives.gov/blog/2014/10/29/innovating-fight-ebola