

# Robotics

Matthew T. Mason and Henrik I. Christensen

This essay summarizes the current state of robotics, and previews the findings of a robotics roadmapping effort currently under way.

Robotics originated with the goal of building human-like machines, but it has become much more than that. Even though we are still decades away from human-like machines, the developing robotics technologies are proving useful in ways that nobody expected: robot-assisted noninvasive surgery; disposal of roadside bombs; automated lab science for drug discovery; even auto-focus features in digital cameras. The broad impact of robotics is proven, even though robotics is still in the early stages of its development.

Robotics thus affords a unique opportunity to make a cross-cutting investment that advances both fundamental research and development in an area vital to U.S. competitiveness while providing the potential for near term job, business development and educational returns. Outlined below are the broad critical application areas for robotics. The creation of a \$100 million initiative to be matched by industry to establish test beds in the major application areas could generate nearly 10,000 new jobs impacting a wide range of sectors. The specific proposal advanced is to create a competitive process to establish a series of robotics test beds in communities across the nation. These test beds would be devoted to specific health, transportation, agriculture, manufacturing and extended care services. The selected test beds must include large and small industrial partners, universities and engaged partners in the end use community. Recognizing the unique capacity of robotics to be a powerful tool for education, each proposal should incorporate a strategy for the test bed to engage K-12 students and to foster the development of new educational applications.

The remainder of the essay addresses the unexpected breadth and significance of robotics.

## **Connecting computers to the real world**

Robotics transforms the connection of computers to the real world. The significance of this connection is difficult to overstate. To start, consider the role of sensors, and the effect on the world wide web, and future networks. At present the world wide web is restricted mostly to documents and other information provided by humans. Even when cameras and other sensors are attached, our computers and networks are primarily a communications and storage medium. Every advance in the software to analyze and understand the sensory data enables numerous applications.

The cost of the sensors, the computers, and the communications is quite low, as evidenced by the number of cell phone cameras in use. As our computers achieve even a crude understanding of video imagery, the applications are many, and will profoundly

change our lives. The most obvious applications are security: pervasive intelligent security monitors for homes, for borders, and for the civil infrastructure will result, and will become more capable and more affordable as the perception techniques continue to improve.

### **Connecting humans to the real world**

Robotics also transforms the connection of humans to the real world. Sensors often transcend the limitations of human perception. They enable us to see far away, to see very small things, to see three-dimensional images of the inside of our bodies, and to integrate imagery from numerous other sensors, such as GPS, motion sensors, and others. This information can be presented to a human in an interactive way, in effect giving a video-game like experience, letting the human experience the world in ways that are now impossible. The most exciting applications are in education. History can be learned by experiencing it first hand. Immersive language learning can become globally affordable. Science students can interact with insects and explore the molecular structure of cells.

### **Robotics in service**

Robotics is about action, and the main goal of that action will be to serve humans. Robotics technology does not resemble common science fiction scenarios. In most instances, robotics technology will be embedded in common objects, and not recognizable as a robot per se. An example is unmanned vehicles. Vehicles are already driving themselves in certain restricted applications such as shipping yards. Unmanned aerial vehicles are proving themselves in surveillance and in combat, and unmanned ground vehicles are nearing substantial deployment in combat zones. When passenger cars drive themselves, the result will be dramatic improvements in efficiency and safety, with enormous savings in fuel, insurance, medical bills, and overall a great improvement in the quality of our lives. Another example is assistive technology in our homes, which can enable the elderly and disabled to live independent lives, rather than moving into institutions.

### **Global competitiveness**

Robotic technology for manufacturing was originally developed in the United States, but the manufacturing robotics industry is now dominated by Asia and Europe, with serious consequences for US robotics and for US manufacturing.

Unlike manufacturing, the service robotics sector is just beginning to develop. Ultimately it will dwarf the manufacturing sector. The United States is well placed, with an outstanding research and development community, and the business infrastructure to encourage innovative applications of the new technology. Nonetheless, we are being outspent by our competitors in Europe and Asia. Our future global competitiveness is at risk if this important new sector is ceded to others.

## **Robotics roadmapping**

Several months ago a group of robotics leaders, drawn from universities, industry, and government labs, formed a roadmapping effort funded by the National Science Foundation. A series of workshops is in progress, with the goal of articulating a national robotics agenda. A National Leadership Council was also formed, comprising leaders from the participating universities, companies and laboratories, which will transmit the final report to the federal government on February 14, 2009.

The goals of the roadmapping effort are: (1) to identify the future impact of robotics on the economic, social, and security needs of the nation; (2) to outline the scientific and technological challenges to address; and (3) to draft a roadmap to address those challenges and realize the benefits. So far four workshops have been conducted. Three workshops focused on application areas: manufacturing, service, and healthcare. A fourth workshop focused on emerging technologies and trends.

**Manufacturing.** The manufacturing sector continues to be vital to the US for many reasons. It is an especially significant part of our exports. Manufacturing practices are changing rapidly in the types of products that can be produced, the quality with which they are produced, and the speed with which new products can be brought to market. Robotics for manufacturing continues to advance, and may be poised for radical acceleration, fueled both by new fundamental approaches to robotics and automation research, and improvements in many component technologies such as perception, machine learning, and human interfaces.

**Medical and Healthcare.** Medical robotics is already a major success as use of minimally invasive robots significantly reduces recovery time and risks associated with surgery. Today a large number of prostate procedures are performed with robots, and a significant number of robot-assisted cardiac procedures are performed daily. Robots are also being used for rehabilitation and in intelligent prostheses to help people recover lost function, and socially assistive robots are being developed capable of providing monitoring, coaching, and motivation for encouraging cognitive and physical activities, and minimizing isolation and depression. Today US is the leader in robot assisted surgery, but other countries are fast followers; it is also the leader in For continued quality of life assistive technologies aimed at special-needs populations and the elderly. For continued leadership, it is essential to push the technology further and to support adoption of the technology and training of physicians.

**Service.** The service sector includes both professional and domestic services. Professional service robots are used in logistics, agriculture, cleaning, and mining. A logistics example is harbor automation to ensure increased inspection of containers to improve homeland security. In agriculture, the primary need is to increase productivity to ensure continued economic viability. In mining, robots are used to increase efficiency but also to increase safety. Other professional services include warehouse management, automatic surveillance of areas etc. Domestic service robots include automatic floor

care such as vacuuming. Already today more than 3 million home robots have been deployed. Robots in the home are essential to reduce time spent on daily chores and enable the elderly to maintain a clean and organized home. Today the US is the leader in service robotics, but is challenged by efforts in Europe and Korea. The service sector is experiencing 400% annual growth and could prove to be a major new economic area. As an example Honda has projected that robotics will be as big an economic sector for them as cars by 2020.

The fourth workshop addressed **emerging technologies and trends**. Robotics integrates many different component disciplines and technologies. Robotics has often been driven by advances in these component technologies, and in return robotics has often provided the applications that have motivated these advances. The roadmapping effort identified 63 different technological advances which promise to impact robotics, and 35 different new applications which will be enabled by various advances. A few specific technology areas of significance are micro- and nano-technology, sensors and motors, the theory and engineering of analyzing and controlling dynamic systems, communication and networking, theory and practice in machine learning, and human interface software.

A national initiative in robotics would address many national priorities. It would ensure future competitiveness and hence employment in a rapidly growing sector. It would directly affect the effectiveness of our nation's military and the security of the homeland. It would enrich our lives by bringing outstanding educational opportunities, good jobs, greater safety, better health care, personal security, and a level of independence and freedom that only our wealthiest citizens presently enjoy.