Robby the Robot

Is Closer Than You Think

By Greg Varhaug

Baxter the Robot, from Rethink Robotics, is capable of sorting, loading, and light assembly.

Meet Baxter

In September of last year, Rethink Robotics introduced a new robot they describe as "the world's first mass-produced, commercial humanoid robot." They call their robot "Baxter." Rethink Robotics is the latest venture by Rodney Brooks, an original founder of iRobot in 1990.

Rethink's brochure states that Baxter "was designed and built with the sole purpose of performing simple, repetitive tasks that are difficult to automate." Unlike traditional industrial robots, Baxter "quickly adapts to changes in its task and its environment." And Baxter is suitable "for jobs such as discrete part handling, loading/unloading lines, machine tending, light assembly, and more."

To make it even more intuitive to humans, Baxter has a display with a virtual "face," including simulated eyes, to show you what it is focused on at any moment. Baxter is a stationary robot. It doesn't roam around the shop floor. You put it in place, and it performs its job.

Baxter is not the result of any single innovation or technical breakthrough in robotics. It's an innovative combination of existing robotic technologies. It is part of a new generation of robots that relies on its vision, combined with its internal logic, to guide its movements, rather than relying on the precise calibration of repeatable movements, as with programmable robotic arms. Baxter's "common sense" is the product of its advanced programming. It is capable of "learning" by experience to better perform its tasks. And its software can be easily upgraded, so Baxter will theoretically become "smarter" the longer you own it.

The first commercial robot designed to interact closely with ordinary humans, Baxter was specifically designed to be touched by the workers who operate it. It needs no programming to learn a task. You program Baxter to perform a task by physically guiding its arms through the motions you want it to replicate. This alone may qualify Baxter as the most versatile commercial robot ever sold.

At present, the most common type of industrial robot is the articulated robotic arm from manufacturers like Fanuc and Motoman. These arms have been in common use for at least thirty years for tasks like welding, grinding, painting, gripping, and so on. Robotic arms are designed to perform specific, repeatable movements quickly and accurately.

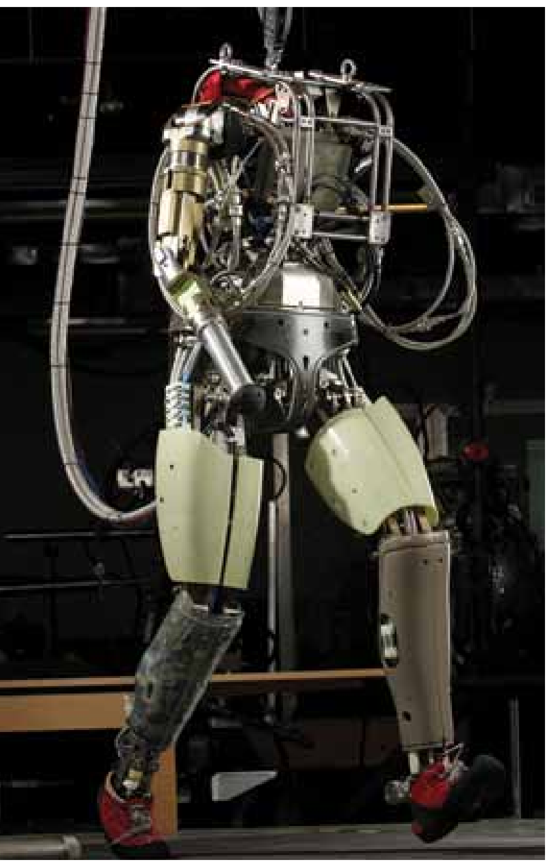
Common industrial robots are extremely dangerous to be around and require protective barriers. They are designed to quit operating if an open gate, weight-sensitive mat, or photo-sensor tells them that a human is present. Even

The Petman Robot is one of today's most advanced humanoid robots. Designed to help test protective clothing, it closely simulates the physiology of the human body. It is also used to test robotic motion-control software. Petman Robot images courtesy of Boston Dynamics.

with these safety features in place, accidents have occurred in which people were seriously injured, or even killed.

Baxter requires no cages or other safety barriers, which eliminates one of the main implementation costs associated with traditional robots. Rethink claims that their robot can be operating within an hour of unpacking it on site. This breakthrough in commercial robotics sells for $22,000. Rethink says it is only selling its new robot in America.

Of course, Baxter isn't all that "humanoid," not by comparison with some of the autonomous, bipedal robots being developed elsewhere. But Baxter has increased the number of jobs, traditionally done by humans, that can be automated. It represents one more decrease in the overall cost of automation.



Developing Humanoid Robots

Many robotics specialists still doubt that autonomous, humanoid robots will be possible, let alone feasible, in the foreseeable future. For years, serious roboticists have scoffed at efforts to develop humanoids as a waste of time. But the fact is that R&D on humanoid robots worldwide has progressed steadily for at least two decades, and the results to date are impressive.

For instance, we've learned how to give robots an acute kinesthetic sense. In humans, this is the sense of feel that tells you when something you're handling is about to break, or when another turn of a bolt will strip the threads. In robots, this is achieved by monitoring the torque being exerted at each joint. Baxter's advanced kinesthetic sense is a result of an active compliant actuation system. This is what allows you to guide Baxter's arm through the motions you want it to perform. And this is the same principle that makes exoskeletons, "wearable robots" that react to your movements, possible.

Some of the most advanced humanoid robots developed so far include a robot from Toyota that can play a song on the violin. Toyota has been developing robots for use in their factories since the 1970s. Their goal is the creation of Partner robots that will be able to care for Japan's rapidly aging population. Honda has created ASIMO, an advanced bipedal robot capable of performing complex dance movements. But neither the Partner nor ASIMO possesses any degree of autonomy or advanced intelligence. In both cases, their movements have been meticulously programmed. Instead, these robots demonstrate the refinements in motion control, including balance, that have been achieved so far.

Clockwise from top: The Petman Robot (Boston Dynamics), Rethink's Rodney Brooks, Baxter the Robot (Rethink Robotics)

Bipedal movement has presented one of the most vexing problems in creating humanoid robots. Designing robots with this ability, so simple and natural to us humans, has proven to be devilishly complicated. Different researchers are approaching this problem in different ways. It requires an extraordinary degree of integration between software and machinery. And as complex as the purely mechanical challenges to creating bipedal movement are, practical solutions depend on developing more advanced algorithms for controlling the robot's motions.

But a robot that can do the work of a human requires more than simply making a robot that can walk. One of Toyota's Partner robots can run on two legs at seven kilometers per hour. The running Partner can also regain its balance if it is pushed, not too hard, by a human, while it is running in place. Motion control in bipedal robots becomes much more complicated when you're designing robots that act autonomously. That's why today's RoboCup soccer-playing robots typically play at the level of three-year-old humans, tripping on their own feet or falling for no reason. And if you want a robot that is bipedal, autonomous, and actively compliant, that complicates matters even further.

Government Robotics Initiatives

The European Union (EU) is involved in several overlapping robotics initiatives, including EUROP, EURON, euRobotics Coordination Action, and others. EUROP involves over 50 companies and research facilities in an effort to make Europe a leader in commercial robotics.

SMErobot, under a separate EU grant agreement, is "The European Robotics Initiative for Strengthening the Competitiveness of SMEs in Manufacturing." SMEs are small to medium-sized enterprises, which make up a large percentage of the EU's economy. Its strategy for improving its competitiveness is "by integrating aspects of cognitive systems" into the future design of robots. One of their specific aims is to create cognitive systems that understand and communicate using the same ideas and symbols as humans. This way, robots can learn from people, and vice versa.

Over a decade ago, the Japanese government started an aggressive initiative to create humanoid robots to assist with elder care. In Japan, where they are actively experimenting with human–robot interaction, robots are being used in hospitals to guide visitors to patients' rooms.

The U.S. government also supports initiatives in robotics. In the DARPA Robotics Challenge, participants are competing to design robots for disaster response. In announcing its challenge, DARPA cited the Deepwater Horizon accident, Hurricane Katrina, and the disaster at Fukushima as examples of situations participants should consider in designing their entries.

DARPA is looking for robots with a high enough degree of autonomy that they can execute simple commands, like lifting a load and moving it. They may have to work their way through debris or other obstacles. They want a robot that can navigate in a human environment. It will have to be able to navigate stairs, turn a doorknob, or operate a switch on a machine. It should be able to perform any task a human could. It's no surprise that most of the entries announced so far are humanoid, though at least one is modeled on a six-legged insect.

For those contestants whose expertise is in software design rather than robotics engineering, DARPA will provide a ready-made bipedal robot, the PETMAN, made by Boston Dynamics. PETMAN is one of the most advanced humanoid bipedal robots yet developed. Its gait and range of movements are startlingly similar to a human's. If it's pushed while walking on a treadmill, it can quickly regain its balance and correct its course.

Robots require a lot of power. A robot working in a disaster area needs to carry enough power to perform its mission and return to a safe location. Part of the DARPA Robotics Challenge is a project to make robots more energy efficient, and to develop more powerful batteries. Another problem designers face is that disaster-response robots will have to be able to work in environments that allow only intermittent or low-fidelity communications.

Apart from DARPA's contest, this past August, the Obama administration announced its National Robotics Initiative (NRI) as part of a larger program to increase the number of manufacturing jobs in America. The goals of the NRI are remarkably similar to those of the

EU and the Japanese government. The White House's Office of Science and Technology Policy describes the NRI as "an ambitious technical agenda for developing next-generation robotic systems that can safely work with humans and augment human capabilities." Much of the discussion by participants in the NRI centers on humanoid robots.

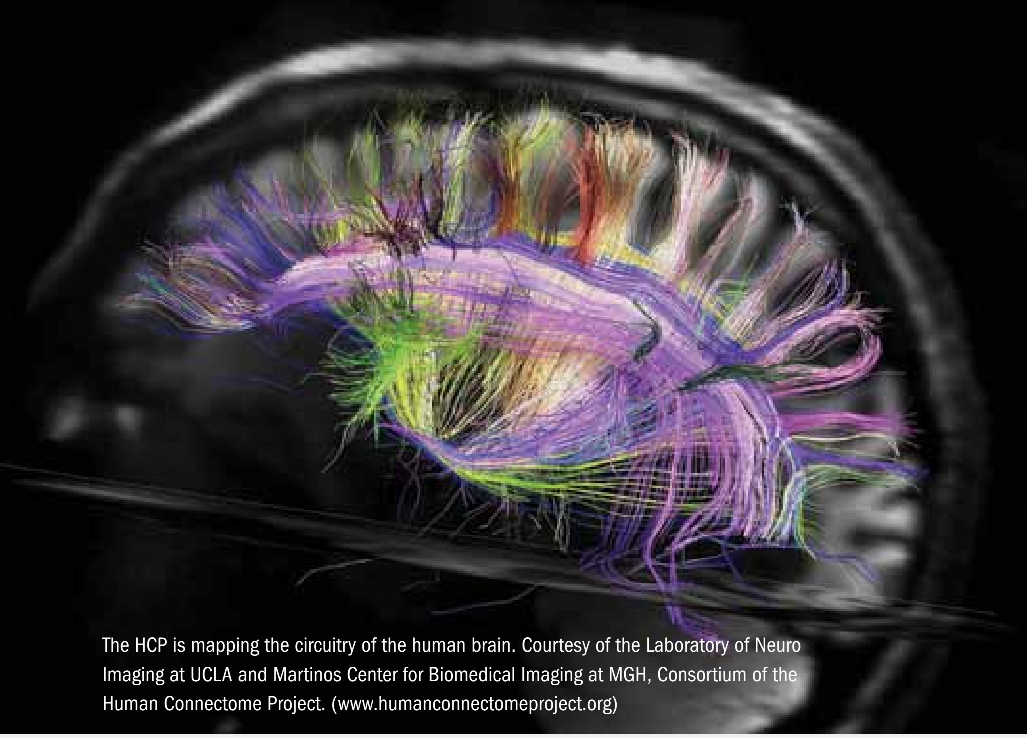
The Futurists

It's hard to predict the precise course of future developments in commercial robotics. Businesses in this young industry are likely to look for the fastest and easiest ways to recoup their R&D costs. For instance, expect to see relatively low-priced domestic robots, capable of only a few specialized functions, available in the next few years. Some of the first domestic robots will be practical; some will be for entertainment. Entertainment robots have contributed quite a lot to the development of robots generally and humanoid robots in particular. The Japanese have developed "androids" to the point that they may pass for humans if you don't look too closely.

Today's machines are nowhere near achieving anything on par with human intelligence. Watson can play *Jeopardy* and win, but it doesn't think. Computers can search data and formulate answers to questions, but they aren't conscious. There again, whether machines are conscious or not, we've reached the point where their capabilities are encroaching into areas that have previously been the sole domain of humans.

Rodney Brooks, Michio Kaku, and Ray Kurzweil are three leading theorists who regularly point out that progress in computer-based fields consistently follows a progression that is exponential, rather than linear. Kurzweil, a well-known inventor and author, maintains that advances in knowledge-based fields such as computers and robotics increase exponentially, in accordance with "The Law of Accelerating Returns."

Speaking at a presentation hosted by Google called *How to Create a Mind*, Kurzweil said, "What's driving this is the exponential growth of information technologies." He points out that



The HCP is mapping the circuitry of the human brain. Courtesy of the Laboratory of Neuro Imaging at UCLA and Martinos Center for Biomedical Imaging at MGH, Consortium of the Human Connectome Project. (www.humanconnectomeproject.org)

Decoding the Brain

The Human Genome Project could not have been completed without computers. There are, after all, about three billion base pairs of DNA in the human genome. In 2009, the National Institutes of Health launched the Human Connectome Project (HCP), a program to map the tissues and connections within the human brain, using the most cutting-edge MRI technology. HCP is much more ambitious than the Human Genome Project, since there are 100 hundred billion or more neurons in the human brain, each connected to thousands of other neurons. This is also complicated by the fact that each human brain is different. Brains change with age and are influenced by environmental factors like exposure to toxins.

Just mapping the structures doesn't tell us everything about their functions or how they interact with other structures. Still, the HCP has revealed structures and relationships in the brain that no one knew existed. The HCP will help to finally answer some of the longest-standing questions about the relationship between environment and genetics in our personal makeup. The brain is still one of the least understood organs in the body.

The stated goal of the HCP is to learn more about Alzheimer's, schizophrenia, and other diseases that affect the mind. Roboticists are watching the HCP because, for one thing, it brings us a step closer to understanding one of the most fundamental and mysterious human mental processes—how we form images, like our memories of sights and sounds, in the brain. It's already possible for a person with a "brain gate," using only his EEG, to precisely control a robotic arm. And it's already possible for computers to "decode" images captured by a human retina and project them, however sketchily, onto a screen. In a lecture entitled "The World in 2030," Michio Kaku predicted that within a couple of decades we'll be able to buy copies of our personal genomes on DVDs for maybe $100 each. He also believes we will have the ability to take photographs of people's dreams.

This image shows the layout of white-matter fibers in the corpus callosum, one of several "fiber bundles" that can be differentiated using advanced imaging techniques. Courtesy of the Human Connectome Project.

the Human Genome Project was only 1 percent complete seven years after it started. At the time, some people predicted it would take 700 years to complete. The project was completed only seven years later. Kurzweil cites the Human Genome Project as an example of an information technology that grew exponentially. He explains that seven years to completion from 1 percent is about right, because seven doublings of one percent gets you to 100 percent.

"I started out with the common wisdom that you cannot predict the future. But if you measure the underlying properties of information technology, the power of computation per constant dollar, of calculations per second per constant dollar, or the number of bits we're moving around wirelessly, or the number of bits on the internet, or the cost of transmitting a bit, the spatial resolution of brain scanning, or the amount of data we're downloading about the brain, or the cost of sequencing a base-pair of DNA ... these fundamental measures follow amazingly predictable trajectories—really belying the common wisdom that you cannot predict the future. And what's predictable is that they grow (or decrease with regard to cost) exponentially."

The science of robotics has evolved into a synthesis of many cutting-edge scientific fields, including electrical and mechanical engineering, optics, computer science, and even biology. Later this year, the University of Houston and the Methodist Hospital Research Institute will sponsor the 2013 International Workshop on Clinical Brain-Neural Machine Interface Systems. Dr Jose Contreras-Vidal, the workshop's conference chair, is best known for his work on a robotic ankle joint that works by reading the subject's EEG. This requires a single, small sensor attached to the subject's head, which actually touches the surface of the brain. The goal of the conference is to produce "a strategic plan for implementation of neural interfaces in the clinic and at home."

It took about 70 years to get from the Wright Flyer to the Boeing 747. The time between the invention of the transistor in 1947 and the release of the first microcomputers was about 30 years. Wilbur Wright could never have imagined a 747, just as no one looking at the first hand-made transistors could have imagined the PC or the iPhone. Today, we are within striking distance of finding solutions to the remaining problems associated with creating compliant, autonomous, humanoid robots. Where these new developments and discoveries will actually take us as a people we can only guess. **N**

Greg Varhaug has written software instruction manuals and procedural manuals for many Houston companies. He operates HoustonGuitar.com, a commercial music-instruction website.