ROS Expands the World for Quadriplegics

By Steve Cousins and Henry Evans

The most compelling use of personal robots is to provide assistance for people with disabilities. For example, many quadriplegics can now move about and interact with the world outside their bodies using telerobotics. Over the past few years, the Robots for Humanity project has experimented with telerobotics, using robots ranging from the powerful PR2 from Willow Garage to relatively simple remote presence devices, such as the Beam by Suitable Technologies, to flying quadrotor robots. Robotics often has a negative connotation because of how robots are portrayed in Hollywood, but Robots for Humanity highlights significant positive uses for the technology. Rather than the robot apocalypse of *The Terminator*, this positive vision is closer to the experience of the disabled veteran in *Avatar* or the benign helpfulness of R2D2 and C3PO in the *Star Wars* franchise.

In this article, we look at some of the uses that a few pioneers have explored and chart out future directions. The robot operating system (ROS) has enabled many of these early forays by letting people quickly build complex robot systems as they imagine them. As more commercially available robots with teleoperation capability become available, technology will enable more people to explore outside of their homes safely and regularly and otherwise expand their capabilities. These technologies are usable by anyone who can, through any means, manipulate a cursor.

Figure 1. Henry Evans controlling a PR2 robot using a head tracker and custom user interface.

Henry Evans

Henry Evans has been a mute quadriplegic for the past ten years. Before the stroke that changed his life, he had been the chief financial officer of a Silicon Valley company. With a wonderful wife and four children, he was living the American dream. After the stroke, it took him a while to figure out how he would continue to make the kind of positive impact on the world of which we all dream. But Henry found a way.

In 2011, Henry saw a PR2 on CNN and realized that it could be a surrogate body for him. Instead of quietly dreaming about it, he described his vision in an e-mail message to Eric Berger of Willow Garage. As he tells it, this was one of many e-mails he sent, but it was one of the few that were answered. In response to his e-mail, Steve Cousins of Willow Garage and Charlie Kemp from Georgia Tech pulled together a project team to build the interface that Henry imagined (and sketched out using PowerPoint) (Figure 1). Henry surprised everyone with how he used the PR2 once he had control of it: he moved the PR2's gripper to his face, and used it to scratch an itch, something he had not been able to do for himself in almost ten years (Figure 1).

The Willow Garage–sponsored Robots for Humanity project went on for over two years, bringing in professors and students from Brown University, Washington University, and Oregon State University in addition to the team from Georgia Tech. Henry was able to use a range of software tools for the PR2 to shave himself, send the robot to get himself a towel to wipe his face, open a refrigerator to retrieve yogurt, and even hand out candy to kids on Halloween at the Stanford Shopping Center. In what may have been the coup de grace, Henry operated a PR2 from his home in Palo Alto, California, to shave Charlie Kemp in Atlanta, Georgia.

Many of the tools built for Henry were based on the ROS visualizer, but the project also explored Web-based interfaces, building on work done at Brown University and the Bosch Research Laboratory, Palo Alto, California (http://robotwebtools.org/). Upon learning of another random e-mail Henry had posted, this one expressing the desire to explore his yard with a camera drone, Chad Jenkins and his students from Brown University set up an AR Parrot quadrotor with a camera

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at Henry's home, which gave Henry a new world to explore. He was able to fly the device over his yard and inspect the grapes in his vineyard and fly it over his home to see the solar panels that had been installed there.

When Chad went home to Rhode Island, he invited Henry to visit him through a Beam remote presence system. Although Henry cannot speak, he used the Beam to look around and play soccer using the Beam's base to move the ball around. He also flew Chad's quadrotors through a Hula-Hoop in the lab there. Henry's description of this remarkable use of technology to go places and do things he had not been able to do with his disability was presented as a TedX talk that has been viewed almost a million times and translated into 25 languages (you can find a link to it on http://r4h.org).

Henry's goal is not just to use the technology to help himself but to make it available to people in situations similar to his around the world. He has made it his mission to get quadriplegics to "go with him" virtually to museums and other places of interest. He is working to arrange soccer tournaments for quadriplegics using robotic technology. In short, his work is making it so that being quadriplegic and mute does not mean being confined to a room in an institution for the rest of your life.

Stuart Turner

Stuart Turner is a quadriplegic in Manchester who got involved with Robots for Humanity through Raffaello D'Andrea. Stuart says, "I saw a TEDTalk of his about drones being flown on YouTube, and I was struck by the idea, to say the least. I emailed him to see if he could help or advise me in accessing drones, as I'm quadriplegic and can't just pick up a remote controller. He put me in touch with Prof. Chad [Jenkins], and I learned then about R4H. It's a fascinating project, and I'm massively glad to be involved."

Stuart connects to the lab in Providence and flies a Parrot AR Drone ("often into the walls, floor, or passing students") using a Web interface. He talks to Chad and his grad students and gives feedback that they use to make changes to the interface. He has also used a Beam telepresence robot to walk around the campus and talk to some of the students, all from 3.5 mi away.

Robots have had a profound impact on Stuart's life. As he puts it, "From the first moment I 'walked' down the corridor at Brown, I began to imagine the possibilities for people like me. I have been restricted to my bedroom for many years, as my wheelchair is so large it can't pass through the doorway. But robots-…robots can go places we can't, and that's true for everybody: they can clean up nuclear waste in Japan, explore the moon, Mars, the inhospitable atmospheres of gas giants, or fly through the halls of a university. It's all part of the same idea: robots expand our reach."

Stuart was a computer science major in college when he began to lose function in his arms and legs due to a condition known as cervical spina bifida. He had to leave the university when he lost the ability to type, but over the last decade, he has developed a pretty decent voice-operated system, using Dragon Dictate, Switch XS, Tracker Pro, Alfred, "and a whole hodgepodge of things," and he can code again without his hands.

Remote presence technology has made a huge difference in Stuart's life: "It's a bit strange that some of the longest conversations I've had since my early 20s have been using the Beam. Using the robot, I am wholly present in its distant location. I haven't found any other technologies that allow me this level of personal interaction with people. Even when I could walk, I was always concentrating fiercely on my feet. And I haven't turned around to look at someone for, probably, a decade. It's these natural physical movements that make such a difference to the experience. It really is amazing!"

Stuart continues, "If I had my own robot, I would probably do mundane things with it. We all would, I reckon. I would go to weddings and funerals and birthday parties—I've missed every one for years—or even just to my friends' houses. Most people don't have wheelchair access in England, so I've never been to the homes of most of my friends and family. I would go to the supermarket and see what they are like these days! I would go to meetings so I could advocate 'in person' for myself instead of relying on other people to speak for me. Once all that had got boring and mundane again, I would probably start exploring: visit museums, attend lectures, climb mountains, travel. But first, I would really like to go feed the ducks in the park at the end of my street."

Mantvydas Juozapavicius

Mantvydas Juozapavicius lives in Vilnius, Lithuania. In 2002, he broke his neck while diving, which left him paralyzed with quadriplegia: "I have been interested in new technologies all my life—toys, computer games, all kinds of computer software, etcetera. After I injured my neck and became quadriplegic, I stayed in intensive care for about two months. When I was released from ICU, one of the first things my parents bought me was a Jouse (a junction of joystick and mouse)—a device that enables me to operate a computer with my mouth. I would have hardly been able to live without a computer before my accident. And even more so after the accident," said Mantvydas.

"So, when I saw a TED video of Henry operating robots, I said 'I also want to operate robots!' It did not take too long to contact Henry and Chad Jenkins. Thanks to them and other dedicated people at Suitable Technologies and Brown University, I had the opportunity to drive a remote presence device in the Museum of Computer History in Mountain View, California, and fly a drone in Brown University in Rhode Island. Both are half a world away! I did just short test drives, but I can already sense the possibilities lying ahead."

"To be frank, robots, for me, are more a source of recreation than a vital necessity (which make them no less amazing and fascinating). I am very lucky to have wonderful parents who take care of me. With the help of my parents, relatives, and friends, I go to concerts, theaters, cafes, and restaurants. However, technology offers so much more! For now, I am not able to imagine being completely independent from other people. (Who is?) But I already do a lot of things on my own—I can communicate with anybody, anywhere; I can shop online. Robots are one more step ahead—I will be able to visit and explore places all over the globe. Feeding or shaving myself is also just around the corner."

"All of this will make life much easier not just for me, but for millions of bedridden people. And I believe the most important thing is to ensure the universal availability of technology, so that no one is left behind."

Joe Karnicky

Joe Karnicky is a retired engineer who has been battling multiple sclerosis for decades. His disease has left him quadriplegic, with minimal control of one arm during the early part of the day. Although he does not use ROS, he has created a similar system of his own to control his home and a small robot arm since he retired 15 years ago. Joe can control his front door, his bedroom window, his wheelchair, and his robot arm using voice commands. He has built a distributed system that runs across six different computers in his home, and he uses his technology to be independent without a caregiver for many hours each day.

Joe loves the outdoors and often has his morning caregiver drop him off at one of the levees near the San Francisco Bay. Joe got connected to Robots for Humanity through one of these trips. It is often windy by the bay, and on this particular day, Joe was driving briskly along the path on the levee when he commanded his wheelchair to turn slightly right to follow the path. "Right nine degrees," he said. But with the wind, the computer heard "right 90 degrees" and promptly sent Joe and his wheelchair off the edge of the levee, down the hill and into a chain-link fence (which probably saved Joe's life by keeping him out of the marsh). Sally Applin found Joe and helped extricate him; she then introduced him to Willow Garage and Robots for Humanity.

The robot arm Joe has is not fancy by robotic standards: it is not large, strong, or precise, but Joe has made it work for him. He can command it directly by saying things like "move up two" or "move back five," but he has also programmed higher-level commands. "You are holding something; throw it away" tells the robot arm to move its gripper toward the back of the table it sits on and then open the gripper—dropping whatever is being held behind the workspace. "Spear me a sandwich" causes the robot arm to grab a toothpick, use it to pick up a bite of sandwich, and hold it out so that Joe can reach it with his mouth. In this way, he can feed himself lunch without a caregiver present.

What's Next?

Telerobotics begins with a person firmly in control, but it really takes off when the robot has high-level built-in commands that the human can invoke.

When Henry tells a quadrotor 3,000 miles away to do a flip, he does not drive it with a joystick—he simply clicks the "flip" button on his user interface, and the device executes a preprogrammed script. Kaijen Hsiao and Matei Ciocarlie of Willow Garage pushed the frontiers of this kind of thinking for interactively manipulating objects. Their work integrated state-of-the-art object recognition with powerful grasping behaviors, so that instead of having to perfectly position a PR2's gripper from another room, Henry could simply click on an object in a camera image and select the "pick up" action.

Telerobotics is not just for people with severe disabilities. Devon Carrow, a seven-year-old boy with extreme allergies, was able to attend school with the help of a VGo telepresence system. At Willow Garage, where telepresence robots were plentiful, employees were encouraged to come to work via telepresence if they were sick to avoid infecting others.

Henry's perspective on disabilities is compelling: from a distance, all humans appear disabled. As humans, we adapted to our environment through evolution. We developed sight, hearing, speech, and so on. Yet these adaptations are quite limited—we cannot run faster than ~25 mi/h, we cannot fly, we cannot stay underwater very long, and we cannot be in more than one place at the same time. All humans are limited by nature in many ways.

As Henry sees it, he may have lost a few of the natural adaptations that evolution afforded him, but he has adapted to these limitations, often in a way similar to how "able-bodied people" have adapted to nature's limitations. For example, he uses a wheelchair to increase his mobility, as someone else might use a bike. He uses a head tracker and a clicker to operate a computer, where someone else uses a keyboard and mouse. He uses a speaking device to be heard, where someone else might use a microphone. We are all quite limited by our physical bodies, and sometimes we use the same assistive devices. If we want to go 60 mi/h, we use cars. If we want to fly, we use jet airplanes. In addition, if we want to "be" in multiple places at the same time, we can use videoconferencing or a telepresence robot, and, soon, a drone.

This brings us to the question "What is next?" Robots for Humanity is currently involved with people from almost a dozen universities (most of them using ROS) to develop robotic and telerobotic applications to help the bedridden and disabled. The projects range from a remote-controlled robotic arm that will scratch facial itches for quadriplegics (independently from a human caregiver), to two different types of telerobotic quadrotor controllers, to a worldwide telepresence tour of museums for bedridden people (including the elderly). If you know of any bedridden people (elderly or disabled) who would like to participate in the tour, which already has interest from museums in California, Washington D.C., London, and Sydney, please have them contact Henry Evans at hevans1000@gmail.com. If they can manipulate a cursor, they can come around the world with us without leaving their bed! Museums from around the world and telepresence companies are also encouraged to participate.

At the end of the day, ROS-based telerobotics will alter our perception of time and space, much like the airplane did 100 years ago. As Morpheus (in *The Matrix*) described it, we will be asking, "What is real? How do you define 'real'? If you're talking about what you can feel, what you can smell, what you can taste and see, then 'real' is simply electrical signals interpreted by your brain."

Next time you see a "disabled" person, remind yourself that you use assistive devices at least as often as he does—and that in many ways, you have disabilities, too. Your disabilities don't diminish you as a person, and neither do his. Now is the time to unleash the power of the disabled through universal robotics, powered by ROS.