HUMAN-ROBOT INTERACTION

The relationship between robots and humans is so different in character from other human-machine relationships that it warrants its own field of study. Robots differ from simple machines and even from complex computers in that they are often designed to be mobile and autonomous. They are not as predictable as other machines; they can enter a human's personal space, forcing a kind of social interaction that does not happen in other human-machine relationships.

Background

The term *robot* first entered literature through the play *R.U.R.* (1920), by the Czech playwright and novelist Karel Capek (1890–1938); *R.U.R.* featured humanoid devices as servants for humans. In the mid-1950s, the first true robots appeared. A human operator working from a distance ran these devices, which had the ability to carry out numerical computations and contained mechanisms to control machine movement. The rest of the twentieth century saw robotics continue to make significant advances in such areas as more flexible motion, refined manipulators (e.g., articulated hands and walking devices), and increased intelligence. Researchers took advantage of progress in computer science and software engineering, including developments in parallel and distributed computing (which allow for more speedy computation through the use of multiple processors and/or computers), and more sophisticated user interface design.

By the 1980s, robotics was recognized as fundamentally interdisciplinary, with major contributions from mathematics, biology, computer science, control theory, electrical engineering, mechanical engineering, and physics. By the 1990s, robots were increasingly involved in automated manufacturing environments, in deep-sea and space exploration, in military operations, and in toxic-waste management. Predictions abounded that robots would become important in home and office environments as well. At the beginning of the twenty-first century, we are closer to the day when various robot entities may be integrated into people's daily lives.

Just as computers began as academic and research-related computational tools but became personal electronic accessories for the general public, robots now have the potential to serve not only as high-tech workhorses in scientific endeavors but also as more personalized appliances and assistants for ordinary people. However, while the study of human-computer interaction has a relatively long history, it is only recently that sufficient advances have been made in robotic perception, action, reasoning, and programming to allow researchers to begin serious consideration of the cognitive and social issues of human-robot interaction.

From Human-Computer Interaction to Human-Robot Interaction

In the past, techniques and methodologies developed under the general umbrella of user- or human-centered computing began by looking at static (unintelligent) software applications and their related input and output devices. Today these techniques are being extended to consider issues such as mobile wireless technology, wearable augmentation devices (such as miniature heads-up displays and cameras), virtual reality and immersive environments, intelligent software agents (both cooperative and autonomous), and direct brain interface technologies. In addition, mobile robotic agents are now poised to become part of our everyday landscape—in the workplace, in the home, in the hospital, in remote and hazardous environments, and on the battlefield. This development means we have to look more closely at the nature of human-robot interaction; and define a philosophy that will help shape the future directions of this relationship.

Human interface and interaction issues continue to be important in robotics research, particularly since the goal of fully autonomous capability has not yet been met. People are typically involved in the supervision and remote operation of robots, and interfaces that facilitate these activities have been under development for many years. However, the focus of the robotics community can still be said to be on the robot, with an emphasis on the technical challenges of achieving intelligent control and mobility. It is only in the early years of the twenty-first century that the state of the art has improved to such a degree that it is predicted that by 2010 there may be robots that answer phones, open mail, deliver documents to different departments of a company, make coffee, tidy up, and run the vacuum. Due to the nature of the intelligence needed for robots to perform such tasks, there is a tendency to think that robots ought to become more like humans, that they need to interact with humans (and perhaps with one another) in the same way that humans interact with one another, and that, ultimately, they may replace humans altogether for certain tasks. This approach, sometimes termed human-centered robotics, emphasizes the study of humans as models for robots, and even the study of robots as models for humans.

Current Challenges

Roboticists—scientists who study robotics—are now considering more carefully the work that has been going on in the sister community of human-computer

Carbo-Powered Robots

TAMPA, Fla. (ANS)—When modern technology was in its infancy, scientists held out the hope that one day robots would cook our meals, do the housework and chauffeur the children to school. That hope has yet to become reality, but hold on: Here come the gastrobots.

Powered by carbohydrates and bacteria, these robots with gastric systems are taking the science to new dimensions by mimicking not just the anatomy and intelligence of humans—but our digestive processes as well.

Stuart Wilkinson, an associate professor of mechanical engineering at the University of South Florida, is pioneering the new subspecialty.

"The main thing I'm shooting for is a robot that can perform some sort of task outdoors for long periods of time without anybody having to mess with it," he said.

Traditionally powered by regular or rechargeable batteries or solar panels, robots lose their efficiency when placed at any distance from a power source or human overseer. But when powered by food—say, fruit fallen to the ground or grass on a lawn—they have the potential to eat and wander indefinitely.

His test gastrobot—a 3-foot-long, wheeled device—uses bacteria to break down the carbohydrate molecules in sugar cubes. The process releases electrons that are collected and turned into electrical current.

Any food high in carbohydrates could be used, the professor says, including vegetables, fruit, grains and foliage. Meat contains too much fat to be an efficient fuel, he pointed out—so the family pets are safe. A gastrobot would be far happier in an orange orchard, stabbing the fallen fruit and sucking the juice to propel itself.

Measuring soil moisture and checking for insect infestations, it could then relay its findings via a cell phone connection to the farmer's desktop computer.

In its infancy, the new generation of robots has a few kinks yet to be worked out. At present, his creation "is a bit of a couch potato," Wilkinson admitted, and requires 18 hours worth of carbo-loading to move for just 15 minutes.

Then there's the issue of, well, robot poop. "We need to develop some sort of kidney," he explained.

Source: Carbo-powered robot holds promise of relief from drudgery. American News Service, September 7, 2000 interaction (HCI), which has been studying technology development and its impact on humans since the 1960s. However, collaboration between HCI researchers and robotics researchers is not as straightforward as one might think. Until recently, much of the work in robotics has focused on integration of increasingly intelligent software on the more slowly evolving hardware platforms. Individual robots with some humanoid qualities have been developed with amazing capabilities, but it has taken years of extensive work to produce them, and they are still not advanced enough to accomplish real tasks in the real world. Human-robot interaction in these examples is studied primarily to find out what can we learn from humans to improve robots. On the other hand, since the late 1990s, much of the HCI community has adopted an explicitly strong emphasis on human-centered computing—that is, on technology that serves human needs, as opposed to technology that is developed for its own sake, and whose purpose and function may ultimately oppose or contravene human needs or wishes.

Because humans are still responsible for the outcomes in human-machine systems—if something goes wrong, it is not the machine that will suffer the consequences or be punished—it is important that as robots become more independent, they are also taught how to become more compliant, communicative, and cooperative so that they can be team players, rather than simply goal-oriented mechanisms.

Another challenge that faces researchers is how much like a human to make the robot. Does the robot's physical form and personality affect how people respond to it? Does the context of the relationship play a role? Are the needs and desires of those who will interact with the robots different in the workplace than they are in the home, for example, or different in dangerous situations than they are in safe ones, or in interactions that occur close at hand as opposed to remotely? Interesting work by the sociologist Clifford Nass at Stanford University shows that often people will respond trustingly to technology and will attribute qualities such as intelligence to technology based on very superficial cues, such as how friendly or unfriendly the messages generated by the technology are. This has serious implications for the design of robots, especially those to be used in hazardous situations or other situations in which safety is critical. What if the robot has qualities that make the human think that it is smarter than it really is? To take another example, if the robot is to be used as an assistant to a disabled person or a senior citizen, would it be desirable to program the robot to act like it has emotions, even if it doesn't really have any? Would this make the users of the robots feel more comfortable and happy about using the technology?

Current Applications and Case Studies

Researchers are attempting to address these questions by taking their robots out of controlled laboratory environments and having them tackle real-world problems in realistic settings with real people as users. The results are bringing us closer to a more human-centered approach to human-robot interaction.

Urban Search and Rescue

One application is the use of robots for urban search and rescue (USAR). These are situations in which people are trapped or lost in man-made structures such as collapsed buildings. For example, after the collapse of New York City's Twin Towers as a result of the terrorist attack of September 11, 2001, small teams of robots were fielded to give limited assistance to search and rescue operations. Because collapsed buildings and associated rubble pose risks not only to the victims but also to the rescue workers—secondary collapses and toxic gases are constant dangers while the workers are engaged in the time-consuming and painstaking tasks of shoring up entry points and clearing spaces—robot aid is potentially very desirable.

Small, relatively inexpensive, and possibly expendable robots may be useful for gathering data from otherwise inaccessible areas, for monitoring the environment and structure while rescue workers are inside, for helping detect victims in the rubble, and eventually perhaps even for delivering preliminary medical aid to victims who are awaiting rescue. For the robots to work effectively, however, they must be capable of understanding and adapting to the organizational and information rescue hierarchy. They must be able to adapt to episodes of activity that may be brief and intense or long term; they must be equipped to help different levels of users who will have differing information needs and time pressures. Most of the robots currently available for these kinds of hazardous environments are not autonomous and require constant supervision.

The rescue workers will have to adapt as well. They will need to have special training in order to handle this technology. Currently robotics specialists, or handlers, are being trained in search and rescue to supplement rescue teams. However, even the specialists are not entirely familiar with the kind of data that the robots are sending back, and therefore understanding and interpreting that data in a time-critical situation poses additional challenges. Teams of researchers led by pioneers in the field, such as Robin Murphy of University of South Florida, are now studying these kinds of problems and work on improving the methodologies so that the human-robot interaction can be more smoothly integrated into the response team's overall operation.

Personal Service Robots

Personal service robots also offer many opportunities for exploring human-robot interaction. Researchers at the Royal Institute of Technology in Stockholm, Sweden, have been working on the development of a robot to assist users with everyday tasks such as fetching and delivering objects in an office environment. This effort has been targeted at people with physical impairments who have difficulty doing these kinds of tasks themselves, and a goal of the project is to develop a robot that someone can learn to operate in a relatively short period of time. From the early stages of this project, this group adopted user-centered techniques for their design and development work, and, consequently, have produced some very interesting results.

Since ordinary people have little or no experience in interacting with a robot, a general survey was conducted to determine what people would like such a robot to do, how it should look, how they would prefer to communicate with it, and generally how they would respond to it. A large proportion of the respondents were positive about having robotic help with some kinds of basic household or other mundane tasks; the majority preferred the service robot not to act independently, and speech was the preferred mode of communication. Experiments with an early robot prototype showed that people had difficulty understanding the robot's orientation (it was cylindrical in shape, with no clearly defined front), in communicating spatial directions, and in understanding what the robot was doing due to lack of feedback.

Further iterations improved the physical design and the interface, and longer studies were conducted in an actual office environment with physically impaired people, who were given the opportunity to use the robot during their work days to perform tasks such as fetching coffee from the kitchen. One of the interesting observations from these studies was the insight that although the robot was the personal assistant of one individual, it also affected other people. For example, because the robot was not able to pour the coffee itself (it did not have any arms), it had to solicit help from someone in the kitchen to actually get the coffee into the cup. Another example was that people passing by in the hallway would greet the robot, although from the robot's perspective, they were obstacles if they were in the way. These findings suggest that even if a robot is designed for individual use, it may need to be programmed to deal with a social context if it is to manage successfully in its working environment.

Robots are working closely with humans in many other areas as well. Robotic technology augments space exploration in numerous ways, and in the military arena robotic units are being considered for surveillance, soldier assistance, and possibly even soldier substitutes in the future. Of perhaps greater concern are the areas in which robots will interact with ordinary people, as it remains to be seen whether the robots will be programmed to adjust to human needs or the humans will have to be trained to work with the robots. The robotic design decisions that are made today will affect the nature of human-robot interaction tomorrow.

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See also Affective Computing; Literary Representations; Search and Rescue

FURTHER READING

Billings, C. E. (1997). Issues concerning human-centered intelligent systems: What's "human-centered" and what's the problem? Retrieved July 21, 2003, from http://www.ifp.uiuc.edu/nsfhcs/talks/billings.html

Center for Robot-Assisted Search and Rescue. (n.d.). Center for robot-assisted search and rescue: CRASAR. Retrieved July 21, 2003, from http://www.crasar.org/

IEEE Robotics & Automation Society. (1995). *Proceedings of the IEEE/RSJ international conference on intelligent robots and systems: Human robot interaction and cooperative robots.* Piscataway, NJ: IEEE Robotics & Automation Society.

Interaction and Presentation Laboratory. (n.d.). Human-robot interaction at IPLab. Retrieved July 21, 2003, from http://www.nada.kth.se/iplab/hri/

Lorek, L. (2001, April 30). March of the A.I. robots. Interactive Week, 8(17), 46. Retrieved August 29, 2003 from http://cma.zdnet.com/texis/techinfobase/techinfobase/+bwh_qr+sWvKXX/zdisplay.html

Norman, D. (2001). How might humans interact with robots? Retrieved July 21, 2003, from http://www.jnd.org/dn.mss/Humans_and_Robots.html

Rahimi, M., & Karwowski, W. (Eds.) (1992). *Human-robot interaction.* London: Taylor & Francis.

Ralston, A. & Reilly, E. D. (Eds.) (1993). *Encyclopedia of computer science* (3rd ed.). New York: Van Nostrand Reinhold.

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media like real people and places.* Stanford, CA: CSLI Publications.

Rogers, E., & Murphy, M. (2001, September). Human-robot interaction: Final report of the DARPA/NSF Study on Human-Robot Interaction. Retrieved July 21, 2003, from http://www.csc.calpoly.edu/~erogers/HRI/HRI-report-final.html

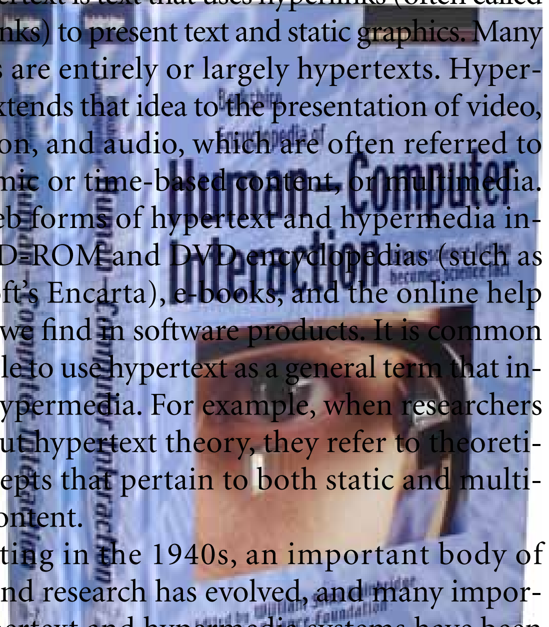
National Aeronautics and Space Administration (NASA). (n.d.). Robotics. Retrieved July 21, 2003, from http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Technology/Robotics/

Fong, T., & Nourbakhsh, I. (2003, March). Socially interactive robots [Special issue]. *Robotics and Autonomous Systems*, 42.

Shneiderman, B. (1997). A grander goal: A thousand-fold increase in human capabilities. *Educom Review, 32*(6), 4–10. Retrieved July 21, 2003, from http://www.ifp.uiuc.edu/nabhcs/abstracts/shneiderman.html

Simsarian, K. (2000). Towards human-robot collaboration. Unpublished doctoral dissertation, Swedish Institute of Computer Science, Kista, Sweden. Retrieved July 21, 2003, from http://www.sics.se/~kristian/thesis/

Takeda, H., Kobayashi, N., Matsubara, Y., & Nishida, T. (1997). Towards ubiquitous human-robot interaction. Retrieved July 21, 2003, from http://ai-www.aist-nara.ac.jp/papers/takeda/html/ijcai97-ims.html



Hypertext is text that uses hyperlinks (often called simply links) to present text and static graphics. Many websites are entirely or largely hypertexts. Hypermedia extends that idea to the presentation of video, animation, and audio, which are often referred to as dynamic or time-based content, or multimedia. Non-Web forms of hypertext and hypermedia include CD-ROM and DVD encyclopedias (such as Microsoft's Encarta), e-books, and the online help systems we find in software products. It is common for people to use hypertext as a general term that includes hypermedia. For example, when researchers talk about hypertext theory, they refer to theoretical concepts that pertain to both static and multimedia content.

Starting in the 1940s, an important body of theory and research has evolved, and many important hypertext and hypermedia systems have been built. The history of hypertext begins with two visionary thinkers: Vannevar Bush and Ted Nelson. Bush, writing in 1945, recognized the value of technologies that would enable knowledge workers to link documents and share them with others. Starting in the mid-1960s, Nelson spent decades trying to build a very ambitious global hypertext system (Xanadu) and as part of this effort produced a rich (though idiosyncratic) body of theory.

Linear and Nonlinear Media

A linear communication medium is one we typically experience straight through from beginning to end. There is little or no choosing as we go. Cinema is a linear medium. In the world of print, novels are linear, but newspapers, magazines, and encyclopedias are somewhat nonlinear. They encourage a certain