What Would You Trust A

by Jeannine Gailey

Dr. Ernest Hall builds robots that learn from their mistakes. Adapt or perish!

Robot To Do?

On any given Saturday this summer at the University of Cincinnati, you will find Dr. Ernest L. Hall, Director of the Robotics Center, in the robotics laboratory with a dozen or so students, eating pizza and comparing ideas for their robot, the Bearcat (named after University of Cincinnati's team mascot), which will be competing in the Intelligent Ground Vehicle Competition in 2004. The students are from graduate and undergraduate programs as diverse as mechanical, industrial and electrical engineering, computer science, and psychology. Dr. Hall, who recently won an Innovative Teaching award, has spent 20 years giving students the opportunity to apply the theory they learn in his classes by designing and building a robot that is capable of guiding itself through an obstacle course.

Dr. Hall is interested in robotics, but also interested in the practical application of engineering design, artificial intelligence theories, software and hardware programming, and plain old mechanical ability. And he wants to make that application fun. That is why students are willing to give up their free time to work in the lab building and programming a robot that can gather information about its surroundings, make decisions, and physically master a series of challenges. This isn't your average Radio Shack robot made for a quick derby battle, content to be driven by a person with a remote control. In many ways, it is a thinking machine.

Why Intelligent Robots?

You can see the potential for thousands of applications – robots that could navigate a street without running over pets or crashing into other objects could perform routine duties such as street cleaning or trash collection. Such robots could also perform risky blood work in a medical lab, or take the strain off overworked hospital staff by doing tasks like delivering meals to patients or collecting soiled laundry. What would you trust a robot to do? This is a key question, Dr. Hall points out, one that both defines and limits the goals of robotic researchers. If a robot is developed that could administer vaccinations, would people trust a robot to do that? But, if the robot could be trained to perform janitorial duties at a nuclear waste site, and this eliminated risk to human life, would people be more willing to trust it then? The practical advantage of robots that can learn is in allowing robots to take the place of humans in dangerous situations, which means having robots that could detect and avoid land mines, or collect hazardous materials at a Superfund site without contaminating safe areas.

Dr. Hall, who has written three books and hundreds of papers and articles on machine intelligence, knows that the idea of an intelligent robot may sound pie-in-the-sky. But he points to examples of intelligent robots that are already in the workforce – the robot lawn mower, robot vacuum cleaner, robot food delivery system and robot helpers for the elderly. Unmanned military ground, underwater, and aerial vehicles are currently beind developed at an accelerated pace as well.

What is Machine Intelligence?

Alan Turing is often thought of as one of the "fathers" of Artificial Intelligence, the science of creating intelligent computers. As early as 1947, he believed machine intelligence would be found in the ability to communicate with natural language. Some "bots" on the web are now savvy in the natural language department. In the 1970s, research into artificial intelligence moved towards creating machines that could respond to visual stimuli, and some scientists tried to replicate the data manipulation of the human brain, building machines with neural networks.

Dr. Hall defines machine intelligence as requiring two attributes. The first is the ability to react to sensory information. "We have been doing this for twenty years," he says. Examples of this today include AIBO, the robot dog from Sony that has the ability to respond to sound, touch, and visual stimuli. However, AIBO cannot learn. "The other, more challenging, aspect of machine intelligence is creating a computer brain that can learn from repetitive actions." With his students, Hall has been studying neural networks in robots – that is, an architecture in which computer processors are interconnected similarly to the way neurons connect in a human brain. This system allows the computer to learn by a process of trial and error. "We need to be more patient with our robots," Hall says. "Giving them time to learn may mean exposing them to not hundreds but thousands of iterations over time." More advanced ideas about neural networking have emerged recently - for instance, the ideas of the adaptive critic and creative learning.

Dr. David Casasent, a professor of electrical and computer engineering at Carnegie Mellon University, and also a researcher in the area of optical systems, has worked with Dr. Hall for over 20 years. "When we started the SPIE Intelligent Robotics and Computer Vision Conference, vision guided robotics was just a research idea. Now we have several of these ideas put into actual practice, such as the Sojourner that is on Mars, and many vision-guided robots in industry and defense."

Q/A With Dr. Hall

JG: What is this adaptive critic learning?

Dr. Hall: The adaptive critic is a form of reinforcement learning that was developed by Paul Werbos of the National Science Foundation (NSF). It uses a back-propagation algorithm of a neural network to distribute error through the network network and make the adjustments needed to learn a given goal. In robotics, it can be used, for example, to make a robot follow a precisely specified path.

JG: How would you define creative learning and how is this approach different from existing techiques in machine intelligence?

Dr. Hall: Creative learning chooses one of several goals - this

WANT TO KNOW MORE ABOUT Intelligent *ROBOTS*?

Web Sites of Interest:

www.robotics.uc.edu - The University of Cincinnati's Robotics web page
www.igvc.org/deploy - The Intelligent Ground Vehicle Competition web page
www.auvsi.org - The main sponsoring organization for the University of Cincinnati robot team
www.ai.mit.edu - MIT Artificial Intelligence Lab site
http://vasc.ri.cmu.edu - Carnegie Mellon's Robotics Institute's Vision and Autonomous Systems center
www.aaai.org/Pathfinder/index.html - A Web site of the American Association for Artificial Intelligence

is the creative part. Once a goal is selected, the adaptive critic can be used to let the robot achieve it. This approach has one higher level of control than the adaptive critic alone.

JG: Tell me a little bit about the robot that you are designing to test creative learning.
Dr. Hall: We have designed the hardware of the Bearcat Cub, a small modern version of our existing Bearcat robot. It has a hybrid power source that will generate electrical power from a small, quiet gas engine. It also uses Segway™ high traction wheels and gearboxes. It also has a web-based Galil™ motion controller and will be run from a Dell laptop. We are also designing creative control and learning software for it.

JG: How does the robot you are working on display decision-making abilities?
Dr. Hall: The robot's program employs decision making logic. It starts by following a line on the ground. If an obstacle is encountered, it must go around, and then return to line following. If the line disappears, it looks on the other side of the path for it.

JG: So, which type of creative learning or machine intelligence does the robot you take to the contest display? And what makes your robot different or more intelligent than, say, the robotic vacuum cleaner that's now commercially available?
Dr. Hall: The type of machine intelligence programmed into our robot for the contest is goal accomplishment with adaptation. That is, during the line following (autonomous challenge) part of the contest, the robot's goal is clear: go the longest distance in the shortest time. It is even given lines to follow. However, along the way there are obstacles to avoid, a hill to climb, a sand trap, an asphalt section where the lines change colors and portions where the lines become dashed and disappear. Adapting in real time to all these changing environmental conditions displays one form of machine intelligence. In the navigation part of the contest, the robot is given waypoints that mark locations on a map. However, it must first determine which waypoint to go to and still avoid obstacles along the way.

Finally, in the follow-the-leader part of the contest, the robot must follow a human driven vehicle at a given distance even when the leader vehicle turns, speeds up and slows down. Each of these adaptive behaviors show a little intelligence.

Certainly, the exploration into intelligent robots that University of Cincinnati's Dr. Hall and his team exemplify what is happening at other colleges in the United States, from MIT and CMU to the more far-flung reaches of Japan, Wales, and Finland. With increased interest and funding, and more everyday applications being solved, these programs will soon be the birth place of the next generation of decision making robots.

AUTHOR BIO

Jeannine Gailey, who has worked at Microsoft, IBM, and AT&T, is currently a consultant and writer whose book on XML Web Services is debuting this fall from Microsoft press. You can learn more about her work at **www.webbish6.com**, and she can be reached at writer@jeanninegailey.com.

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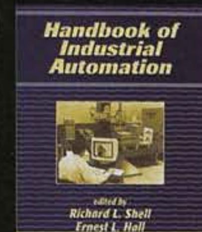
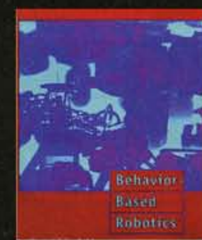
Hanbook of Industrial Automation
Edited by Richard L. Shell and Ernest L. Hall; Hall also wrote ***Computer Image Processing and Recognition***



Behavior-Based Robotics (Intelligent Robotics and Autonomous Agents)
by Ronald C. Arkin



Mobile Robots: Inspiration to Implementation
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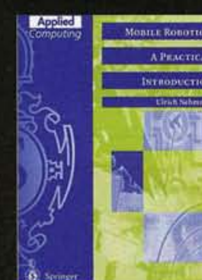

Artificial Intelligence: Modern Approach
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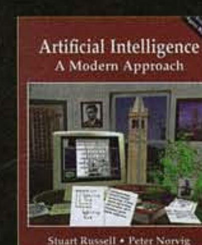

Atificial Intelligence and Mobile Robots: Case Studies of Successful Robot Systems
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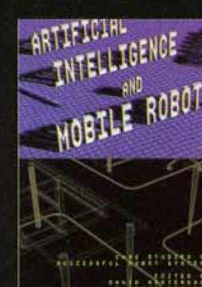

Sensors for Mobile Robots: Theory and Application
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