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Brainy 'Bots

Marshall Space Flight Center

NASA's own "Bionic Woman" is applying artificial intelligence to teach robots how to behave a little more like human explorers.

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May 29, 2001 -- Ayanna Howard may never set foot on Mars or lead a mission to Jupiter, but the work she's doing on "smart" robots will help to revolutionize planetary exploration nonetheless.

As a project scientist specializing in artificial intelligence at NASA's Jet Propulsion Laboratory (JPL), Ayanna is part of a team that applies creative energy to a new generation of space missions -- planetary and moon surface explorations led by autonomous robots capable of "thinking" for themselves.

Above: It might not look like the android Data from Star Trek, but robotic explorers like this one will someday possess artificial intelligence, which will allow them to scout out terrains without human oversight. Image courtesy JPL.

Nearly all of today's robotic space probes are inflexible in how they respond to the challenges they encounter (one notable exception is Deep Space 1, which employs artificial intelligence technologies). They can only perform actions that are explicitly written into their software or radioed from a human controller on Earth.

When exploring unfamiliar planets millions of miles from Earth, this "obedient dog" variety of robot requires constant attention from humans. In contrast, the ultimate goal for Ayanna and her colleagues is "putting a robot on Mars and walking away, leaving it to work without direct human interaction."

"We want to tell the robot to think about any obstacle it encounters just as an astronaut in the same situation would do," she says. "Our job is to help the robot think in more logical terms about turning left or right, not just by how many degrees."

How could a robot possibly make decisions like a human?

Scientists are developing suitable techniques by learning from humans' vision and observation abilities.

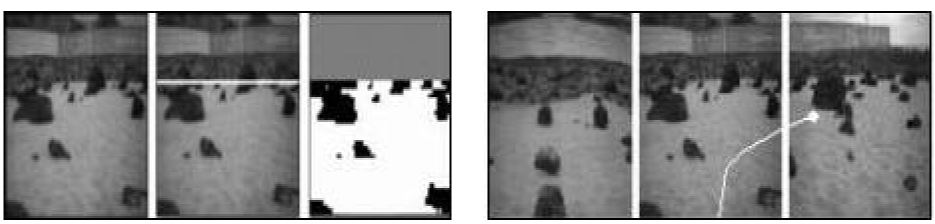
Humans don't have a rulebook or program to consult for each move they make, Ayanna notes -- we're much more reactive than that. Her team's job is to produce robots that can emulate not only the thought process and judgment of a human for sizing up the terrain, but also a human's ability to drive and navigate a car in real time.

Above: Ayanna Howard has a doctorate in electrical engineering from the University of Southern California, specializing in artificial intelligence and robotics. She has worked at JPL since 1993.

To do this, Ayanna and her colleagues rely on two concepts in the field of artificial intelligence: "fuzzy logic" and "neural networks."

Fuzzy logic allows computers to operate not only in terms of black and white -- true or false -- but also in shades of gray. For example, a traditional computer would take the height measurement of a tree and assign that tree to some category -- say, "tall." But a fuzzy logic computer would say the tree has a 78 percent chance (for example) of belonging to the category "tall" and a 22 percent chance of belonging to some other category. The sharp distinction between "tall" and "short" becomes fuzzy.

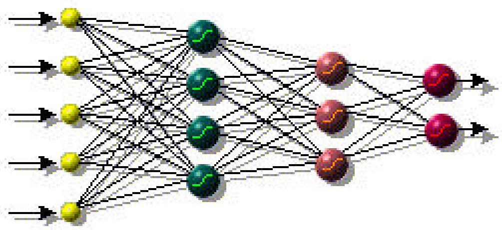
This probabilistic approach to categorization allows the computer to learn from its experiences, since the assigning of probabilities can be adjusted the next time a similar object is encountered. Fuzzy logic is already in use today in software such as computer speech and handwriting recognition programs, which learn to perform better through "training."



Above: The combination of fuzzy logic and neural networks enables robot pioneers to detect the obstacles in an unfamiliar terrain (left, a sequence of one image being processed), assess the relative safety of various alternative routes, and plot a path to its destination (right, a three-image panorama), all without real-time human guidance.

Neural networks also have the ability to learn from experience. This shouldn't be too surprising, since the design of neural networks mimics the way brain cells -- called "neurons" -- process information.

"Neural networks allow you to associate general input to a specific output," Ayanna says. "When someone sees four legs and hears a bark (the input), their experience lets them know it is a dog (the output)." This feature of neural networks will allow a robot pioneer to choose behaviors based on the general features of its surroundings, much like humans do.



To accomplish this, neural nets contain several layers of "nodes," which are analogous to neurons. Each node in one layer is connected to nodes in the other layers. Signals travel through this web of connections with each node acting as a gate, only relaying signals above a certain strength. Adjusting that threshold for individual nodes is how the network "learns."

Above: In this simple example of a neural network, input signals are fed into the yellow layer on the left, pass through the two processing layers, then emerge on the right as output signals. This architecture can perform some surprisingly sophisticated logic, especially when feedback loops are added.

This dinner-napkin sketch of neural nets may sound relatively simple, but in practice, these artificial brains can perform some astoundingly complex logic. In fact, Ayanna calls neural nets a "black-box technology" -- in other words, what happens between the input layer and the output layer is often so difficult to decipher that scientists just treat it as a "black box" that somehow converts inputs into outputs.

By combining these two technologies, Ayanna and her colleagues at JPL hope to create a robot "brain" that can learn on its own how to expertly traverse the alien terrains of other planets.

Such a brainy 'bot might sound more like the science fiction fantasies of children's comics than a real NASA project, but Ayanna thinks the sci-fi flavor of the project contributes to its importance for space exploration.

Right: If and when humans someday colonize the Moon and other planets, autonomous robots will be an invaluable tool for helping people explore the new terrain.

Ayanna -- who wanted to be television's "Bionic Woman" when she was young, and later decided she wanted to try to build her instead -- says she believes that the flights of imagination common in childhood translate into adult scientific achievement.

"I truly believe science fiction drives real science forward," she says. "You must have imagination to go to the next level."

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Artificial Intelligence Group at JPL -- home page

What is fuzzy logic? -- from Pacific Northwest National Laboratory

What is an artificial neural network? -- from Pacific Northwest National Laboratory

JPL's Telerobotics Research and Applications Group -- home page of Dr. Howard's research group

The JPL Robotics Program -- home page

Safe Navigation -- project to develop autonomous navigation technologies being worked on by Dr. Howard

Dr. Ayanna Howard -- home page

NASA's Jet Propulsion Laboratory -- home page

The Shape of Extraterrestrial Life -- ***Science@NASA article***: NASA scientists pioneer artificial intelligence algorithms to search for extraterrestrial organisms

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Would you like to use this story in your 6th to 12th grade classroom? These lessons and activities might help:

- **Brainy 'Bots Reading Guide**: This activity will build anticipation and motivation before reading and generate interesting discussions afterward. [lesson plan][activity sheet]
- **Fuzzy Cartoons!** Students use that fuzzy logic to develop a humorous representation of this fuzzy concept. It's fun but tough. [lesson plan] [activity sheet]

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