Biology proves a natural for robotic design

by Scott_LaFee

The summer movie "Transformers" is loosely based on a popular toy line that features, among other things, robots taking animal form. It's a fantastical idea, but also a case of art imitating life.

Or more precisely, art imitating science imitating life.

NEW ROBOTS - OCTOR is a robot created at Clemson University to mimic the grasping abilities of an elephant's trunk, which can pick up anything from a peanut to a tree. CNS Photo courtesy of Clemson University. Over the years, robot design has generally lurched along two paths: Machines that look like their human creators and machines that look like, well, machines.

The first group, to be sure, remains mostly imaginary - the androids of Hollywood and science fiction.

The second group is more commonplace and workaday. Robotic assembly arms in auto factories don't need biceps like Arnold Schwarzenegger's to do their jobs. The Roomba vacuum cleaner looks like nothing so much as a peripatetic weight scale.

But there's a third path that designers and technologists are increasingly following: robots inspired by nature.

"We're not talking about simply copying nature," said Frank Fish, a professor of biology at West Chester University in Pennsylvania. "That's a trap people often fall into.

"Engineers say, 'Hey, let's just copy nature. It's already done the design work.' But nature isn't forward thinking. Its solutions are tailored to organisms in the moment, and all possible solutions aren't going to be expressed."

Biologically inspired robots, said John Long, a professor of biology at Vassar College in New York, are intended to exploit "fundamental physical principles." In other words, nature's best ideas.

"The Wright brothers learned how to control (a plane's) direction by watching hawks in flight," he said. "They figured out that turning a plane had to do with changing wing surfaces, though not the way hawks did it.

"That's an important distinction. The Wright brothers drew inspiration from biology, but they didn't exactly copy it."

Robotic designs based upon natural organisms are as diverse as the animal world itself. There are devices in the works that mimic caterpillars, spiders, dogs and octopuses. Their goals and purposes are equally varied, from new medical treatments to space labor to being a soldier's best friend.

HEARTLANDER

In Pittsburgh, Carnegie Mellon University researchers are working on a medical device that moves inside the body like an inchworm.

Inserted through a small incision below the ribs and placed with forceps atop the heart, the

three-fourths-inch-long HeartLander latches onto the beating organ with suction cups at each end, moving via remote control commands to places that a surgeon ordinarily couldn't reach without either deflating a lung or fully opening the chest.

Equipped with various tools, HeartLander can take vital measurements, inject drugs or attach smaller devices. In experiments using live pigs, HeartLander has successfully fitted animals with pacemaker leads and injected dye into the heart. Human applications, though, are still several years away.

BIGDOG

One of the biggest advocates of biologically inspired robots is the Defense Advanced Research Projects Agency, or DARPA, a semi-secret arm of the Pentagon that over the years has promoted the development of numerous cutting-edge technologies, from the Internet to stealth planes.

Among its current interests is BigDog, a four-legged, semi-autonomous robot that military planners hope might one day lope alongside soldiers at the front, carrying supplies, weapons, communications and navigation gear, medicine and more.

In early field tests, BigDog already suggests it's a robotic breed apart, lugging up to 150 pounds on its spare metal frame at 7 mph over varied terrain.

There's talk of creating a larger version of BigDog: a robotic pack mule for the Army, which last used the real thing in 1957.

OCTOR

One of the harder challenges with existing robots is that, well, they're hard, often sporting mechanical gripping jaws that are impractical or worthless at picking up large, irregularly shaped or fragile objects.

An elephant has no such problem, notes Ian Walker, a professor of electrical and computer engineering at Clemson University. Its trunk can pick up a peanut or a tree. Walker, with colleagues at Clemson and other universities, is trying to squeeze that elephantine talent into a robot.

Their project, funded by DARPA, is called OCTOR, for "sOft robotiC manipulaTORs." The key component of OCTOR robots is their "octarm," a multi-sectioned, flexible tube powered by compressed air and equipped with sensors and a camera at the tip.

By increasing or decreasing air pressure inside sections of the tube, researchers can move the octarm in any direction and shape it in a wide variety of ways, just like an elephant's trunk.

Functionality is still limited, concedes Walker. OCTOR can't pick up peanuts or tree trunks, but Walker thinks such robots will eventually imitate at least some abilities of elephants and octopuses.

Future versions, he and others say, could be used in manufacturing processes that require complex handling skills. They also could be employed to investigate tunnels, rubble and other narrow spaces - possibly even in backpacks, where they might lend an extra hand.

SPIDERBOTS

In January, a pair of small robots developed by European and Japanese scientists took their first steps in space - not steps, actually, since the robots lacked legs, but the feat was still a giant leap for robotkind.

During the brief suborbital flight Jan. 22, a rocket launched from Japan released a satellite that, in turn, deployed three daughter satellites. These three pulled out a 360-square-yard triangular net with the mother satellite at its center.

From the mother satellite, two palm-sized robots then crawled onto the net like spiders moving across a web. To avoid drifting off in zero-gravity, the spiderbots were equipped with a series of wheels that gripped both sides of the netting.

The experiment did not last very long. One spiderbot stalled after just five seconds of movement; the other after 30 seconds.

Engineers say the problem was likely knots in the net. But they contend the experiment was a conceptual success. They say the technology may ultimately revolutionize the satellite industry because large, costly antennas and solar panels could be launched from small, inexpensive rockets, then assembled in space by tiny robots.

MADELEINE

Not all biologically inspired robots are built to address medical or technological challenges. Some are intended to answer basic questions about life - now or in the past.

That's what Madeleine is doing in a swimming pool at Vassar College in Long Island, N.Y. Her designers want to find out two things: Is it better to use two flippers or four? And how did early marine reptiles like the plesiosaur swim?

Madeleine is an autonomous underwater vehicle that looks remarkably like a small sea turtle, with four protruding polyurethane flippers that are precisely as stiff as the real animal's.

Electric motors on Madeleine's flippers allow them to move in ways dictated by an onboard, remotely controlled computer. Cameras, sonar, an altimeter and an accelerometer monitor the aquatic robot's movements and performance.

"Marine animals use their flippers in different ways," said Long. "Sea turtles, sea lions and penguins all rely on one pair of flippers to propel themselves, while the other pair is used to steer. It's thought, though, that plesiosaurs and giant sea turtles of the past used all four flippers for power."

In tests, Madeleine has shown that four flippers are in fact best for bursts of speed and for quick stops, while two flippers are more efficient for simply cruising at a constant speed.

"Using four flippers for cruising requires too much power because the wake caused by the front flippers interferes with the smooth operation of the back flippers," explained Long.

The results, he said, suggest that plesiosaurs likely hunted by ambush, using short bursts of four-flipper speed to gobble up their prey.

Nature, of course, remains the undisputed champion of design. It has solved countless engineering problems in ways human technologies have yet to match. But designers are trying:

- Tufts University researchers have used the tobacco hornworm as a model for a soft, crawling robot that might someday remove land mines or fix hard-to-reach machinery.

- RHex and RiSE are small, six-legged robots inspired by cockroaches and other arthropods. They are capable of running, leaping over obstacles, climbing stairs and, with modifications, walking up walls and trees.

- At the University of Southern California, researchers are developing a SuperBot, a system of modular, Lego-like units that, like cooperative ants, plug into each other to create robots that can stand, crawl, wiggle, roll, climb and fly (in a micro-gravity environment).

Many of these devices are still rudimentary.

"There's been a massive revolution in robotics in the last 30 years," said Peter Will, a robotics expert at USC's Information Sciences Institute, "but that doesn't mean you'll soon be seeing biologically inspired robots everywhere. A lot of things humans do require far more power and complexity than we can currently put into a machine."

But robotics designers are confident that will change, and the world will be - in a word - transformed.

View videos of nature-inspired robots in action

- BigDog, RHex, RiSE and other robots: www.bostondynamics.com/index.php.

- Madeleine, the aquatic robot: faculty.vassar.edu/jolong/RobotMadeleineVassarCollege.mov.

- OCTOR robot field experiments: www.ece.clemson.edu/crb/octor/multimedia.htm.

- USC's SuperBot: viterbi.usc.edu/news/news/2007/vivid-videos-demonstrate.htm.

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