Published by the International Technology Education Association in *The Technology Teacher*, Vol. 59, No. 6, March 2000.

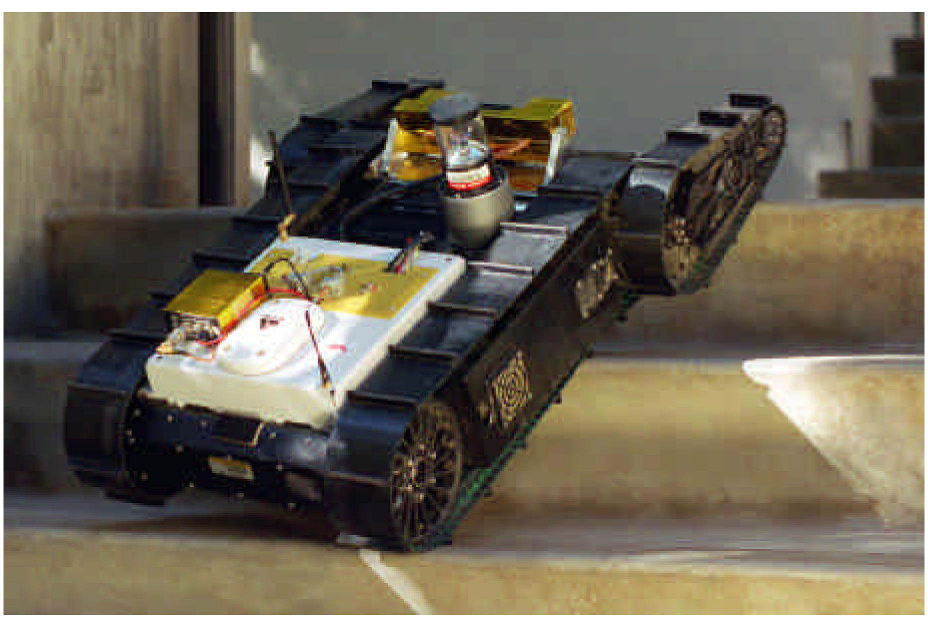
NOTE TO TEACHERS:

Biological systems are often ideal models for technology to emulate. Computer scientists keep trying to create computers that work like the human brain. Human eyesight is another biological system worthy of engineers' respect. In this activity, students will see for themselves the advantage—indeed the necessity in some cases—of stereoscopic vision. It is a simple experiment that can be done as a classroom demonstration with a few students participating and the rest observing, or, if time allows, all students in the class can be given the opportunity to participate.

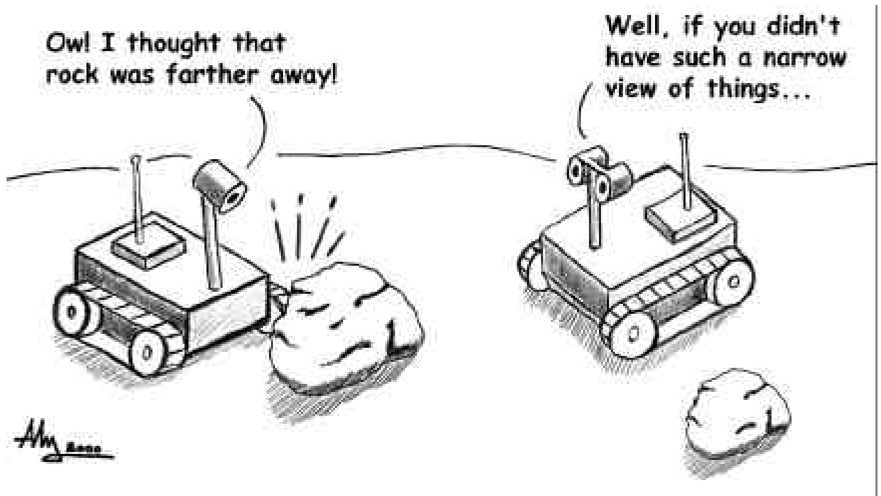
The "Urbie" robot described in this article is being developed by the Defense Advanced Research Projects Association (DARPA), which has enlisted the Machine Vision Group of the Jet Propulsion Laboratory (JPL), California Institute of Technology, to lead its design and implementation. To find out more about NASA's advanced technology programs, go to http://eis.jpl.nasa.gov/technology/ .

This article was written by Diane Fisher and Enoch Kwok. Ms. Fisher is a science and technology writer at the Jet Propulsion Laboratory and developer of The Space Place (http://spaceplace.jpl.nasa.gov), a web site with fun and educational space-related activities for children. Mr. Kwok is a high-school teacher and consultant. The cartoon is by Alexander Novati, The Space Place graphic artist at JPL Thanks also to Nancy Leon, Education and Public Outreach Manager for a number of programs and projects at JPL.

The research described in this article was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.



The Urbie Tactical Mobile Robot is designed to negotiate challenging urban terrain.



BE GLAD YOU'RE NOT A CYCLOPS!

One of the new technologies needed for space exploration is the ability for a machine—say, a robot—to see its environment and react to what it sees. At first glance, this function may seem simple to achieve—after all, video cameras see, don't they? But they don't *do* anything with what they see. That's the hard part. Robots that will be used to explore the surfaces of other planets must be able to do much more. First of all, robots need two eyes, just like us. In this experiment, we will see why.

It's obvious why two hands or two legs are useful, but we have only one nose and one mouth, so why do we need two eyes? Why not have just one big eye in the middle of our forehead, like a cyclops?

Although it's nice to have a backup in case something happens to one eye, two eyes are actually more useful than one even if both are working perfectly. Why?

With only one eye, the world looks flat. Seeing with two eyes gives us stereoscopic vision. This extra ability helps us see things in three dimensions and tell about how far away they are.

Stereoscopic vision helps us navigate our environment and keep ourselves out of danger. While walking quickly on an unfamiliar street, just try stepping off a high curb with one eye shut. Chances are your estimate of the height of the step will be off one way or another, and your landing will be less than graceful.

Just as some advances in computer science are making computers more "brain-like," robotics engineering is trying to copy some of the other well-proven systems of humans and other animals. Stereoscopic vision is one of those systems.

In this experiment, you will see for yourself what a difference an eye makes. You will use a specially constructed, shadowless box for viewing two identical objects. Observing first with just one eye, you will try to determine which of the two objects is closer to you. Then using both eyes, you will try again. One viewing box should suffice for the whole class.

MATERIALS YOU WILL NEED:

- Large cardboard box
- Black construction paper or flat black paint
- 4 identical white objects (golf balls are excellent)
- Transparent tape, stapler, or all-purpose glue
- Ruler

MAKING THE BOX:

Cut off the top of the box. Line the inside of the box with the black paper, using tape, staples, or glue to fasten the paper in place. Or, paint the inside of the box with the flat black paint. Use the ruler to line up the four objects in a row an equal distance apart across the back of the box. If you are using balls, stabilize them by setting them on small rubber washers or small rubber hair bands. You don't need labels of any sort, but for communication purposes name the objects 1, 2, 3, and 4 (left to right).

The eye versus the eyes

Place the box on a table so that the objects will be at eye level with an observer seated about 6 meters (about 20 feet) away. The recorder stands beside the box. The observer closes both eyes, while the recorder arranges the objects so one of them is slightly closer [about 5 cm (2 inches) or less] to the front of the box. Use the ruler to estimate the offset distance of the closer object. Then, keeping one eye covered, the observer opens the other eye and guesses which object is closer. The recorder should not indicate whether the guess is correct. Without changing position, the observer then uncovers both eyes and guesses again. The recorder records the offset distance of the closer object, as well as the accuracy of the guesses.

The data sheet might be set up something like this:

Test #	Offset Distance (cm)	One eye		Two eyes	
		Right	Wrong	Right	Wrong
1	6	X		X	
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Vary the offset distances a bit from one try to the next. When everyone has had a turn to be an observer or recorder, tally up the total correct and incorrect guesses for both one-eyed and two-eyed observations. Are two eyes better than one for determining relative distance to objects? Why? How much of a difference is needed for one-eyed observations to become accurate in this experiment?

Because our eyes are separated by a few centimeters (a couple of inches), each eye sees things from a slightly different angle. If you look at a nearby object with first one eye and then the other, you will notice that the image seems to shift back and forth. Each eye sees a slightly different image. Your right eye sees a bit more of the right side of the object and your left eye sees a bit more of its left side. Your brain, however, sees one image that combines the two. The difference in this one combined image is that it appears 3-dimensional, whereas each of the images from a single eye appears more flat. You will thus be able to judge the depth of the object and its distance from you. Depth perception, by the way, is something your brain had to learn through experience with the world. You were not born with it.

One of the important technologies that must be developed for any sort of free-roaming robot is stereo-scopic vision. Otherwise the robot will not be able to accurately and quickly navigate toward its target, seeing and avoiding obstacles along the way.

Real-time stereoscopic "machine vision" is one of the advanced technologies being developed and demonstrated for the "Urbie" Tactical Mobile Robot. In the past, robots used a single camera as its "eye" and human operators used the picture from that one camera to "see" obstacles and move the robot around to avoid them. This approach doesn't work too well, though, when the robot is moving quickly or in a hazardous situation. There just isn't time for a human operator to analyze the image and react in time with commands to the robot. Also, for exploration of other planets, moons, asteroids and comets, the robot must be autonomous. It takes minutes to hours for an image signal from a robot on a distant body to reach a human operator on Earth and for a command to be sent back to the robot. By that time, the robot could have fallen into a deep hole or gotten itself stuck between a rock and a hard place!

Urbie's initial purpose is mobile military reconnais-sance in city terrain. However, many of its features will also make it useful to police, emergency and rescue person-nel. The robot is rugged and well-suited for hostile environ-ments and its autonomy will make Urbie ideal for working in dangerous situations. Such robots could investigate urban environments contaminated with radiation, biological warfare, or chemical spills.

And, of course, such a robot will make an ideal space explorer.