 SHLOMO MAITAL

Ideas from nature

Scientists are drawing inspiration from the natural world, and using what they learn to help solve problems for humans

A PRAYING mantis, an owl, a pigeon and a chameleon walk into a bar. The praying mantis pulls out a Bible and says to the barman… Actually, this is not the start of a bad joke, and these creatures didn't walk into a bar. They were brought into Prof. Ehud Rivlin's robotics lab in the Technion-Israel Institute of Technology's Computer Science Department.

Rivlin is an expert on robotic machine vision. Helping robots see better, it turns out, is a key part of improving how they function. Over 20 years ago, Rivlin embarked on a risky and challenging research project to better understand vision by studying creatures who see far better than humans. His quest brought him to study birds, insects and lizards. His goal: To make robots that can see much better. And he and his collaborators have succeeded.

NASA's Jet Propulsion Laboratory expert Yoseph Bar-Cohen said at a 2005 conference, "After billions of years of evolution, nature has learned what works and what would last." Survival of the fittest has given praying mantises superb vision so they can snatch flies and mosquitoes out of the air; otherwise, they starve. Natural selection has given similarly sharp eyes to chameleons, owls and pigeons.

Learning from nature is a large and growing field called biomimetics, which means imitating nature in the design of materials and machines. Need tough cable? You could use steel threads, but it is far better to use spider silk, which has tensile strength twice as high as steel. But how do you milk spiders? A decade ago, a creative Montreal-based company called Nexia Biotechnologies worked the following magic: Genes from the spider were incorporated into the milk glands of goats. The resulting silk protein in the transgenic goats' milk was then harvested and spun into silk fibers. It is not as good as real spider silk, but is still tougher than steel.

The most famous biomimetic invention is Velcro. In the late 1940s, Swiss engineer Georges de Mestral took his dog for a walk. As happens to many of us dog lovers, he noticed burrs sticking to his dog's fur. He analyzed the tiny hooks that stuck the seed-bearing burrs to the dog's coat and by 1955 had patented Velcro, a fastener with hooks on one side and soft loops on the other.

Research that combines biology and computer science is high risk, but also high reward

What led Rivlin to tackle a research topic that requires expertise in both computer science and biology? "What drove my research," he tells *The Jerusalem Report*, "was three things. First, curiosity. The fly has a very small brain, with a limited number of neurons, yet it does very complex things, like flying and landing precisely on a certain spot. How? Why? I was curious why praying mantises see so well.

"Second, 'existence proof.' Six or seven professors emerged from my high school class. Why? We were given hard problems in math, told there was a solution and asked to find it. The fact we knew there was a solution motivated us. If we thought there was no solution, we would have worked far less hard on it. So I wanted to prove the feasibility of learning about vision and optimizing machine vision from insects and animals.

"And third, I wanted to research unconventional topics – to create change, to do things better. Research that combines biology and computer science is high risk, but also high reward."

Some 20 years ago, Rivlin wrote a paper with colleagues at the University of Maryland, arguing that to understand vision in sharp-eyed creatures you need to study the purpose of that vision: food, mating and survival. This direction proved fruitful. What Rivlin has done, for instance, is learn how the praying mantis tracks its prey by using high-speed stop-motion cameras. He then built a mathematical algorithm that can be used to build a mantis head "machine eye." He also built a way to simulate "food" for the mantis.

Why is the praying mantis so good at catching its prey? In a 2003 paper, Rivlin and his student Igor Katsman (who is now launching a start-up) found that the insect likes to move its head from side to side (a technique known as "peering," which also gives it its name, because peering resembles praying). This creates "motion parallax," a way to judge depth by the intersection of two different sight lines. The mathematical model Rivlin built to capture this technique was then incorporated into a robotic camera.

I recalled meeting a sculptor, Joe E. Brown, during my student days at Princeton. Brown had lost an eye while training as a boxer. For depth perception, you need two eyes. How could Brown sculpt without the ability to judge depth? He solved the problem creatively, by placing his subjects on a moving turntable. His single eye judged depth by seeing objects in two places (two sight lines),

20.4x24.92	32	עמוד 42	the jerusalem report	30/12/2012	35119801-8
שמואל נאמן מוסד למחקר מדיניות לאומית בטכניון - 85300					

Owls' eyes are fixed in their sockets, so the owl uses its highly flexible neck to revolve its head

rather than having two eyes seeing an object in one place. He went on to become America's leading sculptor of sports figures.

Pigeons, owls and chameleons also have superb vision, each in their own way. Pigeons bob their heads up and down for the same reason the praying mantis "peers" – to create two intersecting sight lines on a scrap of food, so its peck will be fast and accurate. Owls' eyes are fixed in their sockets, so the owl uses its highly flexible neck to revolve its head; owls spend a third of their time revolving their heads like radar.

IN CONTRAST, the amazing chameleon has eyes that move independently in their orbits (unlike human eyes, which must move together). This helps the chameleon track its prey and "fire" its sticky tongue precisely to catch it, like an Iron Dome battery pinpointing an enemy rocket. Rivlin has studied all of these creatures, learned the secrets of their sharp vision and works to incorporate them into his sharp-eyed robots.

I asked Rivlin about possible uses of improved machine vision. He mentioned "docking," a crucial procedure which requires sharp vision and is used, for instance, on the International Space Station, or even in asking a robot to plug an electrical cord into a socket. The military, of course, is keenly interested in robots and in robotic vision. It could be helpful for observation drones.

During an open house held by the computer science faculty, I saw a demonstration of a helicopter drone. Rivlin said that his lab is studying dragonflies, whose aerobatic capabilities far exceed those of helicopters, to improve those drones. Dragonflies have been around for 350 million years. The first helicopter flew in 1939, only 73 years ago. No wonder dragonflies are better at flying.

I asked Rivlin what he is currently researching. He said he is trying to create an improved "virtual reality" for his creatures, to simulate "food" so that their behavior can be studied more effectively. He is also trying to scale up his praying mantis research, so that seven at a time can be studied rather than just one.

I asked him: How can this help researchers like yourself better connect with real-world problems? His answer was simple: "Recently, at a workshop, doctors met with researchers and recounted the problems and challenges they faced. This helped the researchers learn about real-world problems that might also be challenging and fascinating research topics."

For nature lovers, be assured that Rivlin, his colleagues and his students all treat the creatures they study with love and affection.

In a popular TV show in the 1970s, Steve Austin – the Six Million Dollar Man – fights evil with his bionic muscles and bionic left eye. Though Rivlin would not claim so, machine vision may one day help sightless people to see, or help sighted people to see even better. And again, science fiction will become reality, as it so often does. ■

The writer is a senior research fellow at the Technion's Samuel Neaman Institute.