true numbers may never be known, because most are expected to have faded to blackness.

–GOVERT SCHILLING

Govert Schilling is an astronomy writer in Utrecht, the Netherlands.

NEUROSCIENCE

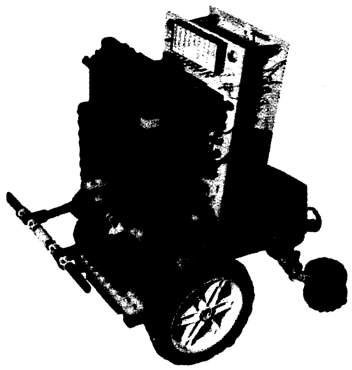
A Machine With a Fly's-Eye View

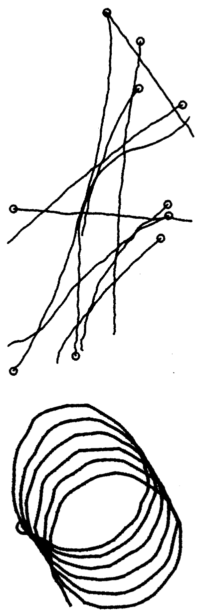
Watch a house fly dart through a kitchen, navigating around obstacles at top speed, and you may not be surprised to learn that this blight of homemakers is a favorite of neurobiologists. For more than 30 years, they have measured brain activity and movement in tethered living flies to learn how the tiny fly brain processes fast-changing visual information and turns it into flight commands. More recently, they have used computer simulations to try out their theories on how these processes work. Now, scientists have a new tool that may help them unravel the secrets of a fly's agility: an analog electronic circuit that models a key part of the fly's visual system and is built into a rudimentary robot so that it can interact with the real world.

The robot fly was developed at the California Institute of Technology (Caltech) in Pasadena by Christof Koch and graduate student Reid Harrison, who says it may turn out to be a better probe of the fly visual system than experiments with live flies or computer simulations. "By building a model that interacts with the real world in real time, one can easily expose the model to complex stimuli that might be difficult to simulate," says Harrison. The robot fly's eye may also benefit robotics, because its analog design is fast, very stable, and uses little power. "[These experiments] show that much can be learned from biology for robotics," says fly vision expert Martin Egelhaaf of the University of Bielefeld in Germany.

Harrison and Koch, whose results will soon be published in *Neural Computation* and *Autonomous Robots*, based their visual system on three layers of structure in the fly's eye. The top layer of photoreceptors each send a signal to a cell called an elementary motion detector, which detects motion by working in concert with neighboring EMDs. When a photodetector picks up a signal, its EMD compares that signal with what its neighbors are seeing. If a neighbor detects an identical but delayed signal, then the EMD decides that they are coming from a single source moving in that direction and sends a message to the next layer of cells. These are the large "horizontal system" (HS) cells, which collect the outputs from all the EMDs and sum them to produce a signal that drives the fly's motor system to react to the detected motion.

The researchers duplicated this structure in a single integrated computer chip. Each electronic EMD consists of a light detector and a simple circuit to compare signals and generate an output signal—all covering an area 60 by 200 micrometers. The chip contains 144 such devices arranged in a 6-by-24 grid. Each EMD in the array sends its signals to another circuit—the equivalent of the HS cells—that sums the outputs to produce a response to the observed movement.





Seeing straight. This robot naturally wants to move in loops *(bottom right)*, but a fly-inspired vision chip keeps it in a straight line *(top)*.

To see if this vision system would successfully respond to real-world stimuli, the researchers mounted it on a wheeled Lego robot. The robot had two powered wheels with very different gear ratios, so it naturally ran in tight circles. The vision system would therefore see a lot of horizontal motion and produce a large signal. The team wanted to use the signal to get the robot to compensate for the motion and move in a straight line. So the Caltech team used the output from the vision system to boost the power driving the low-geared wheel and reduce the power driving the high-geared wheel. Hence the more the robot turned, the bigger the signal, causing the small wheel to run faster and the big wheel to run slower and hence slowing the turn. This optical feedback worked well, and, with the vision system installed, the robot moved in near-straight lines despite the huge asymmetry in its wheels.

Insect vision specialists told *Science* that the success of the robot is an important validation of current theories of fly vision. Alexander Borst of the University of California, Berkeley, believes the way the Caltech vision array feeds straight into the motor system, and hence gets automatic feedback, mirrors biology well. "The big advantage that I see is that the visual system is automatically in a closed loop, which neuroscientists usually forget when thinking of the computational tasks of the visual system," he says.

The nature of the circuits may also hold lessons for roboticists. The vision system contains no digital electronics, which would involve a complex computational recipe containing thousands of operations, but instead uses analog circuits, processing light signals by employing the innate physics of the device—a technique pioneered by Caltech's Carver Mead. This makes its power consumption extremely low—just 5 microwatts for the array. Harrison compares this with the charge-coupled device imagers on the Sojourner rover used in the recent Mars Pathfinder mission. These used 0.75 watt just to acquire images, and much more power to process the data.

The Caltech researchers are now continuing to refine their vision controller system, while at the same time giving their robot fly a smaller and more biologically inspired body that they hope might one day take flight. In particular, they are in the process of designing micromechanical "halteres": vestigial wings that assist a real fly with attitude control and stabilization.

–SUNNY BAINS

Sunny Bains is a scientist and journalist based in the San Francisco Bay area.

COMPUTER SCIENCE

Internet Security Code Is Cracked

A popular encryption tool for keeping credit card numbers and other information secret on the Internet has been cracked. Last week, scientists announced at a press conference in Amsterdam that, using a sophisticated mathematical algorithm and cleverly written software, they had broken the RSA-155 code, which protects credit card transactions and secure e-mail in Europe. The number-crunching legerdemain suggests that anyone trafficking in confidential information on the Internet may soon have to switch to more sophisticated encryption software.

Using RSA-155, one party can send a secure message to another by using the recipient's "public key"—a 155-digit product of two large prime numbers—to transform the original message into ciphertext. Decoding the message, however, requires the two prime numbers, known only to the recipient. For a long time this encryption was considered secure. Factoring a 155-digit number was thought to be beyond the scope of practical computations.

Two years ago, however, a group led by Herman te Riele of the Centre for Mathe-

CREDIT: REID HARRISON

matics and Computer Science (CWI) in Amsterdam succeeded in factoring a monster 180-digit number belonging to a special set, called Cunningham numbers, that are easier than ordinary numbers to factor. After improving the software and the algorithm—called Number Field Sieve—used for pinpointing likely prime numbers, Te Riele's team, including researchers from CWI and from Microsoft and Sun Microsystems, devoted 5 months on 300 personal computers and a Cray 916 supercomputer to finding the two prime factors of a 155-digit number. "Our aim was to show that in principle this can be done," Te Riele says.

For the moment, he says there's little reason for European users to worry that someone will snoop on their Internet credit card purchases—cracking the code still takes too much computing firepower and expertise. He figures it won't be long, however, before such code-cracking becomes common enough to threaten ordinary users. "The situation can become unsafe in 2 or 3 years," he says.

One of the inventors of the RSA code says he had already reconciled himself to someone breaching the code. "I and fellow cryptographers have been recommending for a long time that keys of that size are too short," says Ronald Rivest, a cryptographer at the Massachusetts Institute of Technology. All Internet commerce, says Te Riele, may soon have to move to the more intractable codes—involving 232 digits—that are now standard in the United States or the even longer codes of 309 digits used for government and military transactions. At the current rate of progress, says Te Riele, even his group would not succeed at breaking such codes for at least another 25 years.

10941738641570527421809707322040357612003732945449205990913842131476349984288934784717997257891267332497625752899781833797076537244027146743531593354333897
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102639592829741105772054196573991675900716567808038066803341933521790711307779
×
106603488380168454820927220360012878679207958575989291522270608237193062808643

Choice multiple. A 155-digit number with its two prime factors, identified by Herman te Riele and his team.

CREDIT: CWI

–Alexander Hellemans

Alexander Hellemans is a writer in Naples, Italy.

NEUROSCIENCE

Probing Alcoholism's 'Dark Side'

New Orleans—Alcoholics, it seems, may drink not just to feel good, but also to avoid feeling bad. At least that was the message delivered by new results on the brain chemistry of rats presented at the American Chemical Society meeting here last week by neuroscientist George Koob of The Scripps Research Institute in La Jolla, California. Work by his team shows that in animals, brain levels of a neurotransmitter associated with stress responses skyrocket during withdrawal from alcohol. The finding buttresses a long-standing view that addicts take their drug of choice as a form of self-medication to prevent depression and stress.

Enoch Gordis, head of the National Institute on Alcohol Abuse and Alcoholism in Bethesda, Maryland, calls the finding "very important." Knowing that this stress neurotransmitter, a small protein called corticotropin-releasing factor (CRF), is involved in alcoholism may provide a new target, he says, for gene hunters who are looking for the genetic changes that make members of some families more susceptible to the condition than others. In addition, it could help pave the way for novel medications that combat the anxiety associated with alcohol withdrawal.

"When you're dependent, you're drinking to restore your brain's reward system to its normal balance."

—George Koob

Over 15% of people who try alcohol wind up becoming addicted. But treating the disease has proved difficult because biochemically alcoholism is anything but simple. Alcohol affects several families of neurotransmitters, initially stimulating the release of dopamine in the amygdala and the nucleus accumbens, the brain's reward centers. The levels drop to normal with continued drinking, however, and medicines that target these centers—modulating the effects of dopamine—"have been something of a disappointment" in treating alcoholism, says Koob. That suggests that other factors are involved in dependence, leading the team to explore what Koob calls "alcoholism's dark side"—the reinforcement that alcohol could provide by eliminating the withdrawal symptoms of anxiety and depression.

In the mid-1990s, Koob and his colleagues—who include Floyd Bloom, editor-in-chief of *Science*—began focusing on CRF. The brain peptide works both through the pituitary gland and directly in the brain to trigger the release of hormones and other changes that spark arousal, vigilance, and mood changes. These responses are healthy when dealing with, say, an attacking predator, but over the long haul they can produce chronic anxiety—symptoms that are also linked to drug dependence. One study from Koob's group that looked at marijuana withdrawal showed that CRF levels jumped threefold when mice habituated to marijuana were injected with a compound that countered its effect (*Science*, 27 June 1997, p. 1967). Similarly, alcohol-dependent rats forced to go on the wagon show classic anxiety signs, such as avoiding unfamiliar places. And in one early study, when Koob and his colleagues injected CRF-blocking peptides into the rats' brains, they found that the stress responses fell dramatically.

So in the current study, Koob and his colleagues decided to take a closer look at CRF. Bert Weiss and other Scripps team members started by implanting tiny tubes in the brains of rats to allow them to monitor the concentrations of the peptide in the animals' cerebrospinal fluid over a period of weeks. They found that to start with, the levels were similar in both normal controls and alcohol-dependent rats, but when the dependent rats were forced to go on the wagon, their CRF levels shot up 10-fold. The researchers are currently studying what happens when they start drinking again. Koob says his team is not sure why CRF levels increase during abstinence, but it may be because alcohol suppresses another brain neurotransmitter called glutamate, which in turn is thought to spark the release of CRF, and once that suppression is gone, CRF levels soar.

But the rise in CRF apparently isn't the only brain neurotransmitter change underlying alcohol dependency. In another recent rat study, Koob and his colleagues showed that brain levels of the reward-inducing dopamine drop to half their normal amount during withdrawal and return to normal levels when alcohol-dependent rats drink. Together, the low dopamine and high CRF levels may provide a powerful stimulus to drink. "It's a double whammy," says Koob. "When you're dependent, you're drinking to restore your brain's reward system to its normal balance." That, he adds, could help explain why during their first year of treatment only about half of alcoholics are able to kick their drinking habits.

–Robert F. Service