mouse shows how analog neuromorphic devices can be combined with conventional digital computers, melding the latter's high-precision number-crunching with the fast, lower-power pattern analysis that animal brains have evolved to do. But if neuromorphic devices have so much potential, why are there only hundreds, rather than thousands, of researchers working in the field?

One reason is that analog computing has been a victim of the relentless improvements in digital-chip technology. Chip manufacturers are reluctant to invest in an analog speech-processing device, for example, when constantly improving computing power offers new ways of approaching the problem digitally.

Nervous niches

Given this dynamic, neuromorphics engineers are concentrating on niche applications in which the advantages of biologically inspired computing cannot be ignored. For researchers working on mobile devices that must function autonomously, for example, the energy efficiency of neuromorphic devices is appealing.

This is the logic behind using neuromorphic technology to produce 'bionic' implants. Current cochlear implants, used to restore hearing to some congenitally deaf people, contain mechanical versions of the hair cells that sense incoming sound waves. Artificial cochleae are relatively crude, using between 10 and 20 electrodes to simulate the input of 30,000 or so hair cells into the auditory nerve, but the results can be impressive. In the best cases, the implants allow their wearers to conduct telephone conversations.

But current devices use a bulky and power-hungry digital-signal processor that has to be worn externally. And the implant itself also needs recharging every few weeks, when the wearer is forced to sit next to a charging station for several hours.

Toumaz Technologies, a spin-off from Imperial College in London, now aims to produce a smaller, lower-power analog version of the digital-signal processor. Chris Toumazou, the electronics engineer behind the project, says the device, including both new, low-power electrodes and his processor, will fit within the ear and will only need recharging once a year. He hopes to begin clinical trials before the end of the year.

Toumazou is also starting work on turning the analog retinas pioneered by Mead and Mahowald into practical medical implants. This will be more difficult than developing cochlear implants because preprocessing in the retina is much more complex, and many more nerves are involved — there are 1 million fibres in each of our two optic nerves, compared with 30,000 in each auditory nerve.

Meanwhile, Ralph Etienne-Cummings, an electronics engineer based at Johns Hopkins University in Baltimore, is working on a circuit that will mimic the way the human spinal cord regulates muscle contraction in the legs during walking. Although we are not consciously aware of it, walking requires sophisticated and continuous real-time computation. Our spinal cord integrates information about our balance and leg positions to calculate the right set of muscle contractions. Etienne-Cummings has teamed up with Iguana Robotics of Mahomet, Illinois, to create a chip that might one day be implanted into the spinal cords of paraplegics to help them walk again.

Even the strongest enthusiasts for neuromorphic engineering accept that the current number of products — one computer mouse — is not that impressive. But a range of successful biological implants would be a different matter. "It's been a bumpy road," says Andreas Andreou, a collaborator of Toumazou's based at Johns Hopkins, "but things are now looking very exciting." ■

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Chips offer insights into vision

Neuromorphics engineers are professional plagiarists, freely borrowing their ideas from nature's bag of computational tricks. But the flow is not one way. By building silicon models of animal brains, researchers can also learn about biology.

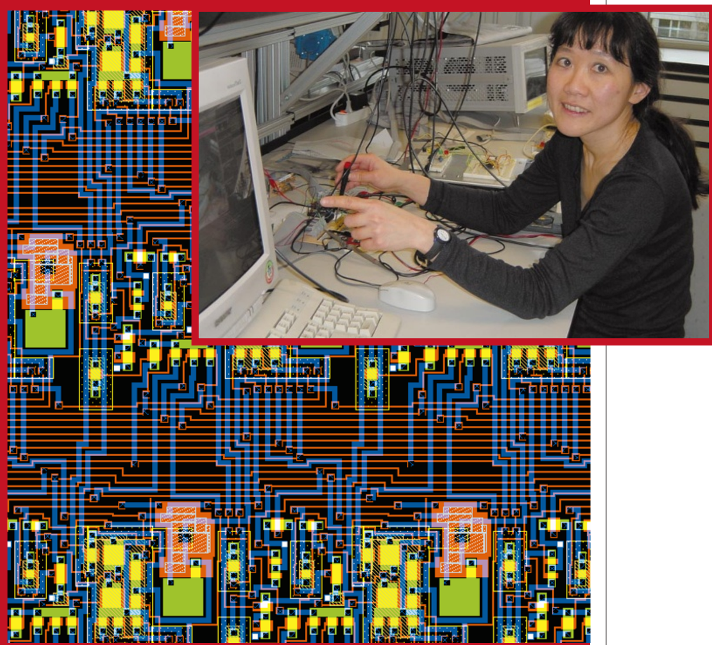
Many neuromorphics engineers pay lip service to this idea, but researchers at the Institute of Neuroinformatics in Zurich are putting it to work. Neuroscientist Kevan Martin and electronics engineer Shih-Chii Liu are collaborating on a project to investigate how our brains process visual images.

The project centres on a device made by Liu called the cortical chip, an analog silicon circuit based on part of the human visual system. Our brains analyse images using a series of different areas of the cerebral cortex. The first of these, known as 'V1', performs low-level processing such as detecting motion and the orientation of lines.

Liu's chip attempts to model two of V1's six layers. It uses a network of artificial neurons connected to mimic the links between layers 4 and 6. Layer 4 is interesting because it receives many of the inputs to V1. To make the chip as realistic as possible, the input to the chip is also taken from biology. Martin has recorded the activity of neurons in part of the cat brain involved in sending signals to layer 4 of V1. Liu feeds these recordings straight into her chip.

Liu can adjust the connections and properties of the artificial neurons to see how they affect the performance of the whole network. By tweaking specific parameters — such as the number of links between layers 4 and 6 — Liu generates insights that Martin can relate to neurophysiological studies. "The number of questions we have to answer is overwhelming," says Martin.

For example, Martin is interested in how different neurons in layer 4 form specific 'receptive fields' — in other words, why each responds to a different area of space within the eye's field of view. Each neuron's receptive field is thought to be controlled by inputs from another brain area known as the thalamus. But Martin suspects that there is more to it than that. "Fifty per cent of all connections to layer 4 neurons come from layer 6," he points out. "So what does layer 6 do? With this circuit, we can adjust the layer 6 synapses and use real data to find out."



Visual clues: Shih-Chii Liu has designed an analog chip that models some of the brain processes involved in image analysis.