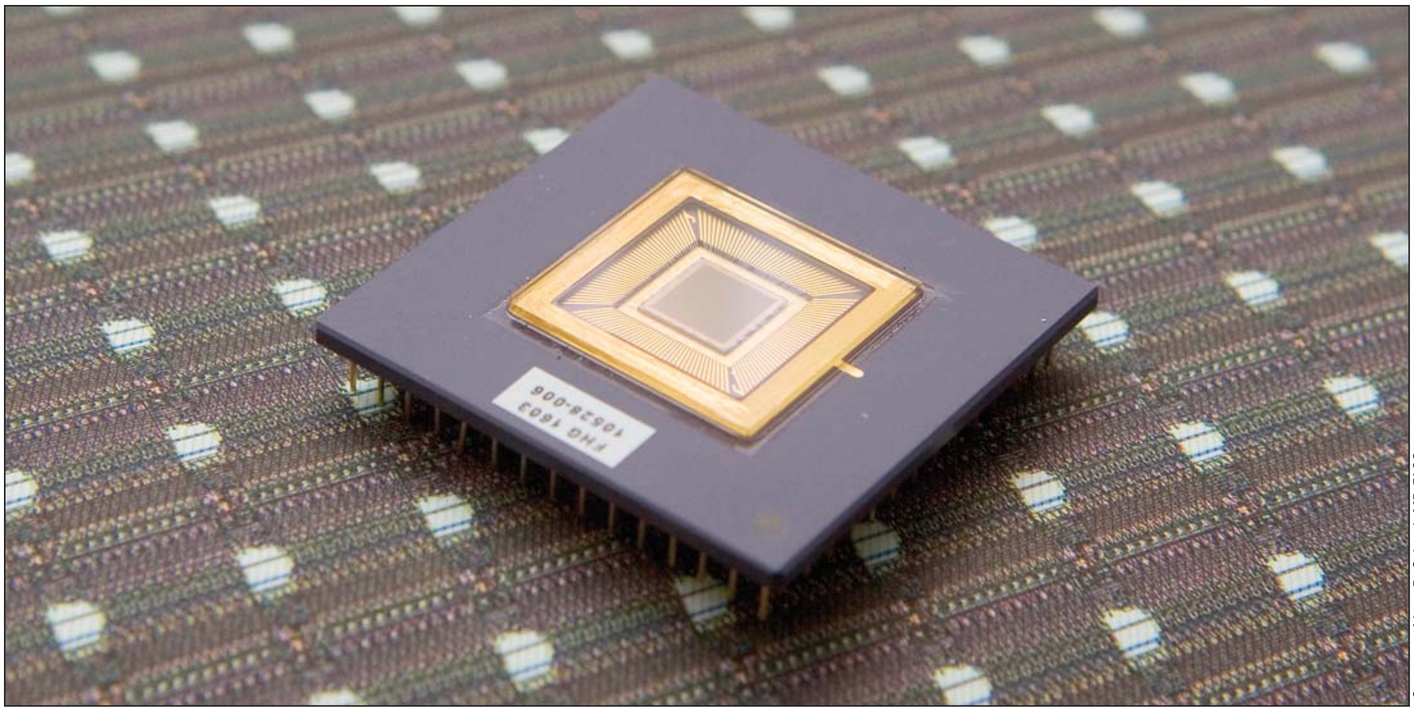
By Daithí Ó'hAnluain

Retina provides model for new vision chip



Courtesy of Ivan R. Schwab MD FACS

New computer chip designs are advancing the field of machine vision, in part by imitating human visual processes.

A major project launched in the UK plans to develop a new robot with an advanced visual system that can recognise objects. Researchers modelled the robot's vision system on the vertebrate retina. The project involves experts in robotics, vision systems, software design and engineering from academic and commercial partners.

If successful, it would be an advance on current systems. Object recognition in the sort of variable environments encountered by robots is very difficult. Machine vision typically requires extremely constrained environments and the device must be programmed to recognise relevant features.

Currently object recognition systems work in environments such as fruit quality selection. Lighting, the speed at which fruit passes in front of the camera and type of analysis required are all pre-determined. In these types of systems the cameras are attached to fixed computers. They require significant, and expensive, processing power that hampers their mobility. Fruit quality recognition systems work by using size and the unique light signature reflected from ripe fruit to determine selection. The next revolution is a system that can overcome these constraints.

REVERB project

The UK project, called REVERB, hopes to build that system. It will use the Scamp chip, which was developed by Dr Piotr Dudek at the University of Manchester after seven years of research. Scamp has a unique architecture. It measures 1.0 cm and contains 16,384 microprocessors. The project will use the Scamp-3 chip for initial experiments, but Dr Dudek believes that system will be improved over the course of the project.

"The Vision Chip will be based on the retina of the human eye and will work in a similar way giving the robot excellent peripheral and central vision. Like the human eye, the chip will process very complex images at rapid rates filtering them through to the robot's brain and enabling it to react in real time," said Dr Dudek.

The team use CMOS (Complementary Metal-Oxide Semiconductor) sensors, with pixel-parallel processors for peripheral vision, which is the main focus of the project. The central, foveal vision will either use the vision chip or a conventional CMOS or CCD (Charge-Coupled Device) digital camera. The technical specifications may change as research progresses.

Dr Dudek compares his chip to the human retina because the chip performs some image-processing tasks on the focal plane, next to the 'photoreceptors'. It then passes this information to a higher-level processor for further processing, just as a human retina performs some low-level image pre-processing before it passes the signal to the visual cortex.

"As in a retina, a massively parallel array of processors results in very fast, low power operation," said Dr Dudek.

Dr Dudek said that some research questions must still be answered. For example, models of vertebrate visual processing need to be developed. This will determine the architecture of the chip.

"Then we face a challenge of the circuit and layout design, fitting the required functionality into the smallest possible silicon area, as well as providing right interfaces for the rest of the system," said Dr Dudek.

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"This project will enable researchers from a number of disciplines and institutions across the UK to work together to understand how animal nervous systems integrate sensory information in guiding behaviour, and then to transfer these insights to the building of robotic platforms," said Dr Kevin Gurney from the University of Sheffield, leader of the REVERB project.

The researchers believe the new technology could be used for carrying out tasks such as machining and inspection of aircraft parts. Other ideas include building devices to assist the disabled or infirm.

"Our basic premise is that nature builds systems very well, and if we can mimic those systems then we hope to be able to build better robots which combine the best of both the computer and the human worlds," says Dr Dudek.

He also believes his device could, potentially, be applied to bionic vision. He believes that a cortical or retinal implant will need to do some visual pre-processing, in real time while combining small size and low-power consumption. He added that the chip might need to be programmable to suit the needs of individual patients.

"All these features are available with our vision chip technology, so in principle it could be a promising solution, but we are not currently involved in any of the bionic eye projects," said Dr Dudek.

Biomimetics

Dr Dudek work is only one among many projects around the world that are taking inspiration from nature, a trick known as biomimetics. This is not new in science or robotics. Famously, seeds from the burdock plant inspired Swiss inventor George de Mestral to develop Velcro in the 1940s. Burdock seeds use little hooks to hitch a ride on passing animals.

In vision, too, biomimetics flourishes. The AnaLogic company in Hungary has developed an interest in systems based on cellular vision chips. This chip uses an array of tiny visual sensors, processing by integrating image acquisition, storage and computing in a single device. It processes on the focal plane in real-time, like Dr Dudek's chip.

Similarly, neuromorphic microchips attempt to mimic neurology. Neuromorphic chips are analogue, not digital, which means inputs are registered across a range of values rather than the 1's and 0's of digital systems. Analogue is not as exact as digital, but it is faster. Digital chips, on the other hand, use slow and complex computing cycles to attempt to mimic the analogue response.

A project at the University of Utah in Salt Lake City illustrated the neuromorphic concept with a chip inspired by the optic lobe in a fly's brain. The project identified the various processes taking place in the lamina, medulla and lobular-plate cells in a fly's brain and implemented them in silicon.

A 'pixellated' light sensor reads an image using an array of individual cells, with additional circuitry built locally into each cell to process the incoming signals. The fact that these processing circuits are local and analogue is crucial to the device's operation.

Roving eyes on Mars

While research will continue for a long time on an unconstrained object recognition chip, practical and dramatic applications of computer vision are already in action. Currently the two Mars rovers, Spirit and Opportunity, are still beaming back images of the red planet. So far the two machines are operating more than 16 months longer than expected, and NASA plans to continue the mission through September 2006.

The rovers' stereoscopic vision played a role in their longevity. The vision system enables to two robots on Mars to avoid obstacles, such as big rocks they can't climb over. The Jet Propulsion Laboratory's Machine Vision Group developed the vision system and the software to run it.

It's an early application, as are all current machine vision systems, but it indicates the power this tool will bring over the coming decade.

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