Dmitri Vitaliev visits three Toronto men who have created a functioning camera eye – an invention with far-reaching applications

the eyeborg man

KOSTA GRAMMATIS

THE HISTORY of technological breakthroughs is littered with simple questions producing groundbreaking answers. In an unremarkable townhouse in suburban Toronto, Canada, one-eyed film maker Rob Spence questioned why, if something as compact as a mobile phone could encase a digital camera, his eye socket couldn't do the same. His answer was to replace his optical prosthesis for one with a video camera; the result could form the background of a revolution in optical technology.

Teaming up with Steve Mann, a professor at the University of Toronto and a lifelong inventor of wearable video cameras, Spence taksed himself with creating an implanted 'sousveillance' device. This term was coined by Mann to describe the recording of an activity from the perspective of its participant – the inverse of surveillance.

"Our original intent was to produce a system that would collect video for reasons of personal safety, filmmaking and electronic news gathering, with the eventual goal of helping people see better," says Mann.

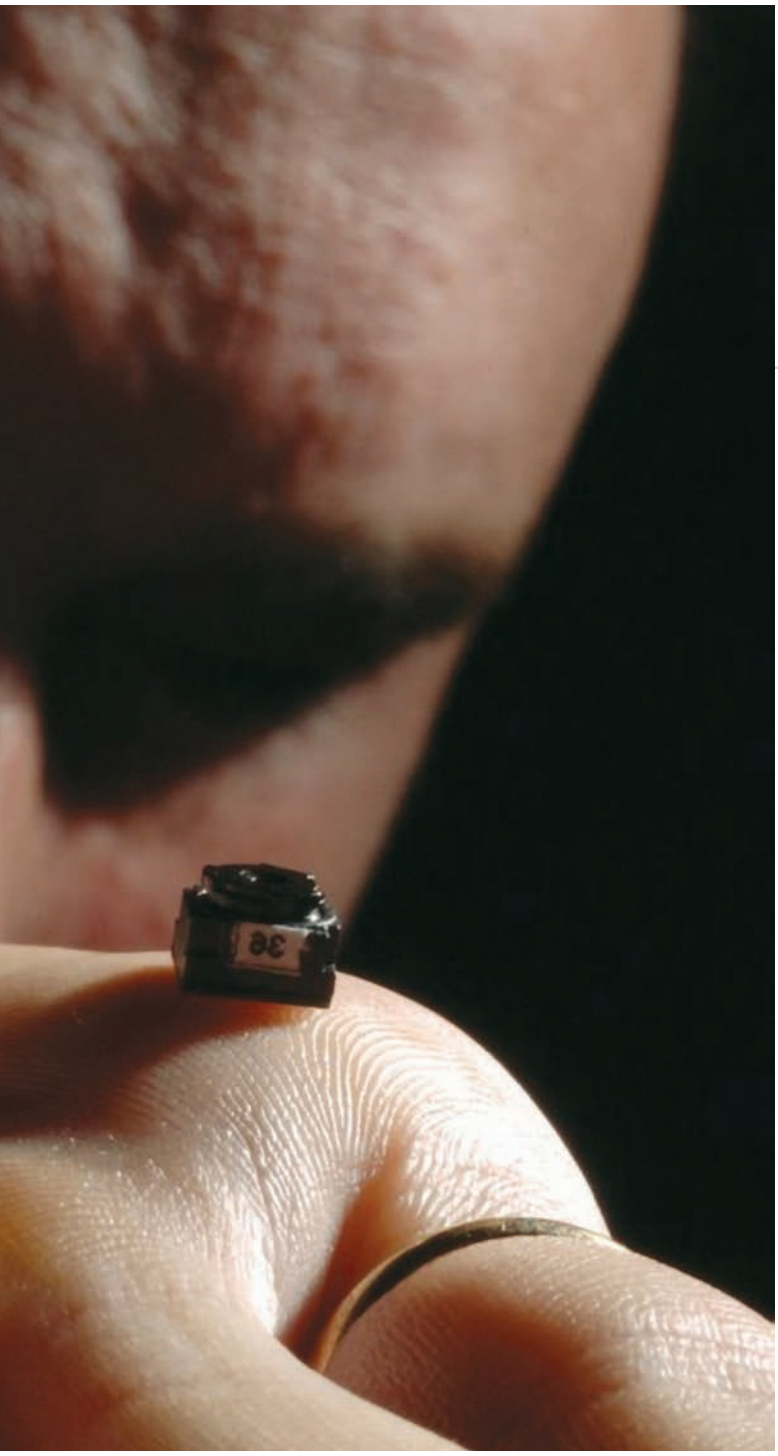
On 23 March 2009, Rob Spence recorded two minutes of video footage from a camera implanted in his eye prosthesis. The image was sent wirelessly from a transmitter located in the prosthesis to a television set nearby. The Eyeborg man was born.

Standing next to Spence was Kosta Grammatis, a young self-taught engineer from Westwood, California, who had designed and developed this proof of concept. He volunteered, having moved in to Spence's spare bedroom after reading about the idea in *Wired*. Grammatis gives the impression of an inventor with a calling, an engineer driven by youthful resilience.

School-time afternoons at the local Radio Shack, lunch money spent on components, and the creation of a bedroom security system using reclaimed electronic equipment dumped by his neighbours – these were the first steps in the life of this young inventor. He once blew off half his thumb, broke his hands and damaged his face during an experiment with explosives.

At college, he constructed an air balloon with a remote deflation system to conduct high-altitude air quality and pesticide research. An on-board computer controlled the capture and storage of air samples in small motorised tubes. Two wireless video cameras, a Web server, and a comprehensive telemetry system allowed monitoring of data from the ground.

He soon joined SpaceX, a space transportation company developing partially reusable launch vehicles, where he was responsible for a team working on over-horizon telemetry solutions. This involved the development of a telecommunications system for use with the Iridium satellite constellation. His project is now in orbit, part of the Falcon 1 space capsule.



Rob Spence considers a mobile phone camera for his eye prosthesis

TECH SPECS OF THE VISION SYSTEM

"It's really quite simple", explains Grammatis. "We're using an endoscopy camera soldered to a printed circuit board (PCB). The wireless transmitter receives an NTSC signal from the camera ward and relays to a recording device in Spence's backpack. The battery is lithium polymer, also used in many Bluetooth headsets. Everything is cased inside a $3cm^3$ custom-built two-piece prosthesis, which Spence can easily insert and remove from his eye socket."

The project caused a stir in the media, and the young entrepreneurs have found themselves without a moment to spare between interviews for CNN, Fox News and the Canadian Broadcasting Channel. Yet popularity has not brought fortune. Entirely self-funded, they rely on donations of equipment and technology from interested commercial enterprises.

The shift from a prototype to a functioning model ready to be used as a permanently wearable video recording device reveals the complexity of the problem and the technology involved. Contrary to Grammatis's claim, it is not "really quite simple".

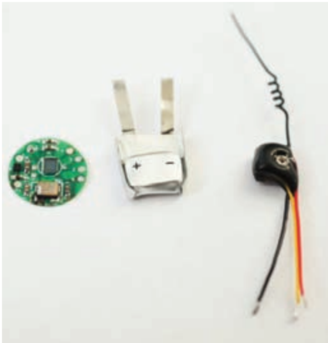
The camera used for the prototype, donated by Omnivision, is typically found in medical endoscopes. Its rather low 400 × 200 resolution is not suitable for recording video on the street. The colour CMOS censor functions in a low-light environment and one peak at the Sun may blow it. It is extremely small, with a packaged footprint of only $1.8mm^2$. Five wires connect it to the PCB (itself the size of a penny) and require its location nearby. "It could all be smaller," Grammatis remarks.

The biggest issue is power. Current consumption required for the camera and wireless transmitter hovers around 52mA. The 3.3V 10mAh lithium polymer battery provides for about three minutes of continuous supply. Grammatis is considering several solutions.

It may be possible to prolong a battery's lifecycle with kinetic energy from the body. Much like an automatic watch, a weighted rotor would turn a tiny electrical generator to provide constant power. It would be housed in the back lobe of the prosthesis.

Electromagnetic induction could deliver power wirelessly. A backpack with an energy supply and an RF transmitter can charge the battery. Distance between the source and receiver is crucial. The Boston Retinal Implant project has connected an image from a video camera, housed in a pair of sunglasses, to a person's retina. The circuit on the retina is powered using RF induction. Its antenna coil is only a few centimetres away from the transmitter on the glasses.

A captured image recorded directly to a device in the prosthesis could get rid of the transmitter, reduce power consumption and create additional space for batteries. A microSD card would collect several hours of footage, but yes, there will be a need for an encoder and frequent withdrawal of the eye – imagine a user discretely plugging an eye into a laptop with a USB cable.



CMOS camera, lithium polymer battery and wireless transmitter

Many possibilities but few ready-made technologies exist. Earlier this year, a $9mm^3$ hydrogen fuel cell was unveiled by researchers at the University of Illinois. A thin membrane separates a water reservoir from a chamber containing metal hydride, beneath which is an assembly of electrodes. Water vapour reacts with metal hydride to form hydrogen, which in turn reacts with electrodes to form electricity. But it doesn't provide enough sufficient current nor voltage as yet. "Maybe we'll just put solar panels on his eyelids", jokes Grammatis, "but then his head will shadow them".

For now, the solution revolves around reducing power consumption of existing devices and creating a custom-made lithium polymer battery. Grammatis is on the job sourcing donations of a camera with a built-in transmitter. "It will probably be the smallest camera of its type in the ▶

EXISTING WEARABLE CAMERAS

Netcam During 1994-6 Steve Mann designed, built and continually wore a wireless camera on his head. The captured image was streamed on the Internet. By the late 1990s, the device fitted onto a pair of sunglasses.

CritterCam *National Geographic*'s Crittercam is a research tool designed to be worn by wild animals. It combines video and audio recording with collection of environmental data such as depth, temperature, and acceleration.

SenseCam A camera from Microsoft that can record images when triggered by changes in movement, temperature or light. Its purpose was to help people with memory loss recollect the day.

'A microSD card would collect several hours of footage – imagine a user discretely plugging an eye into a laptop with a USB cable'

world," he claims. "A few days ago I put together a 30mA battery. This should do us for an hour of charge."

Did I mention he was 23? And looking for a 'real' job?

THE PROSTHESIS

The prosthetic eye itself is another invention from a young Canadian, named Phil Bowen. An apprentice ocularist, Bowen had to create a two-piece prosthetic, one of the first of its kind in the world. Not heeding advice to drop this crazy project, he pursued it with a passion for modernising and pushing the limits of his field.

Spence lost his eye from the recoil of a shotgun, during a hunting accident in Northern Ireland. At the age of just 13, his eye contents were removed by doctors, explains Bowen, leaving only the sclera. They inserted a coral implant – which is porous, allowing muscles and blood vessels to grow – and a titanium motility peg at the back of the socket to aid movement. This makes it much more difficult to shape the new prosthesis to the socket, but enhances its movement and creates a more natural impression.

Even though the two-piece prosthetic is a self-contained unit and there is little danger of battery liquid or other chemicals leaking, problems and concerns remain. The risk of infection, especially as the constant trials and short battery-life require frequent removal, is present. Mounting the camera and PCB correctly in the frontal lobe takes a lot of precision and guess work. Most importantly, it remains to be seen how well Spence's eye socket will respond to the new implant. Will technology placed in the prosthesis affect its acceptance by the body?

For the inventors though, the potential benefits and applications greatly outweigh today's challenges. Past projects have shown that different body parts, such as tongue and back, can be taught to become light receptors for the brain. It may be possible to stream the image from the camera directly to the retina,

Rob Spence wearing the see-through prototype

partially restoring vision. Cosmetic and psychological benefits exist for the wearer without immediately obvious signs of their disability.

AESTHETIC POTENTIAL

Although they have not yet decided on the 'look', Spence's prosthetic can be coloured to match his other eye and therefore disguise the camera. The camera lens looks out from where one would expect the black of the iris. Alternatively, they are considering a see-through prosthesis, making all aware that they are speaking with an Eyeborg – opening up plenty of opportunities for fashion (an LED would go down great at parties) or functionality (a laser light would be the envy of boardroom presentations).

"My face is the medium, the message, the problem and the solution," says Spence. "For a documentary film maker, a camera eye opens up a whole new point of view that is closer to the human experience." Intimate conversations that rely on body language, eye contact and the assumption of privacy may never be the same again.

Feeling uncomfortable? That is Spence's original objective. By turning himself into a Little Brother, he wanted to highlight people's concern (or lack of it) for issues of privacy and surveillance. The City of Toronto is planning to install 12,000 surveillance cameras without much fanfare, public discussion or debate. However, those who have heard about the Eyeborg on television, radio and in dozens of newspaper articles do voice an opinion on Spence's ethics and the legality of recording video without due permission from its subjects.

And so, Kosta Grammatis, Rob Spence and Phil Bowen have created a functioning camera eye. Its immediate future and application lies in the hands of those who are able to donate technology and share their experience with the creators. Whether this feat of engineering and self-sacrifice will lead to an increase of invasive paparazzi, new frontiers for investigative journalism, a generation of EyePods, in-your-face reality-shows, plain clothed Little Brothers working for the State or a lowering of your insurance premiums – remains to be seen. But it is a wonderfully interesting project, built on the back of youthful persistence and a belief that everything is still possible. ■

■ The Eyeborg Project needs your support. For further information and details of where to send donations and advice, visit:
Project website: www.eyeborgproject.com
Kosta Grammatis's website: http://iamkosta.org
Steve Mann's website: http://genesis.eecg.toronto.edu/
Boston Retinal Implant project: www.bostonretinalimplant.org/

RESTORING VISION

Last year, a 73-year-old man received experimental surgery at the Moorfield Hospital to install a bionic eye, the Argus II. Developed by the Californian-based Second Sight, the project uses a camera and video processor mounted on sunglasses. The captured image is sent wirelessly to a receiver implanted on the eye. The signal is forwarded through a tiny cable to the electrode array, stimulating it to emit electrical pulses. This induces a response in the retina and is passed through the optic nerve to the brain, which perceives patterns of light and dark spots corresponding to the electrodes stimulated. Patients learn to interpret the visual patterns produced into meaningful images. **See feature, p18.**