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# The cutting edge of virtual reality

**Forget blood and guts, tomorrow's medicine is all about robotics, augmented vision and creating VR images of the body**

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Microvision

VINNY, with his shiny dark hair and unreal tan, is lying on a hospital trolley dressed in a lightweight green surgical gown. A young woman listens to his heart as his chest gently rises and falls. He blinks, and his pupils dilate, as a bright light is shone into his blue eyes. Adjusting Vinny's head, she pushes a plastic breathing tube into the back of his mouth, past his vocal cords and into his lungs. To her satisfaction, a


light breeze flows in and out of the end. Then, she strips back his gown. There is a large, loose, rubbery flap of skin just above his pubic bone. She peels the flap back. Underneath is a mess of electrical wires and rubber plumbing.

Forget blood and guts, tomorrow's medicine is about bits and bytes. Vinny is a humble digital mannequin, designed to simulate trauma (and if necessary death) for his military buddies to practise on, but he was only a small part of the technology on show in January at Medicine Meets Virtual Reality in Newport Beach, California. Doctors, engineers, computer scientists, military men and an assortment of researchers met to discuss computer-based tools for medical diagnosis, training, telemedicine, image-guided and minimally invasive surgery.

Robot assisted, and computer enhanced, surgery is a rapidly moving field. Techniques already arriving in surgical theatres include robotic keyhole surgery on the heart. Much research is focusing on improving current practice—say, by taking blood samples more accurately using a robot—as well as overcoming problems in areas such as microsurgery. Robotics is set to push forward the frontiers of what is humanly possible, even under a microscope.

“Many VR helmets give a narrow view of the world—like watching a mini–TV through a cardboard tube.”

Although microsurgery is currently used in a wide range of operations, including limb reattachment and reconstructive plastic surgery, it is difficult and not always successful. And there is a lower limit to what is operable because of hand tremor, the control of forces and the fundamental limits of co-ordination and positioning. Below a millimetre in size, vessels and nerves are difficult to repair, and the very smallest cannot be reattached. This is a particular difficulty in finger reattachment in children, where the sutures can be a third to two-thirds of a millimetre in size. As more successful anti-transplant drugs arrive, a way must be found to reconnect the tiniest of vessels if limb reattachment is to become a routine operation.

Pablo Garcia and his colleagues at SRI International in Menlo Park, California, are developing a robot which mimics the surgeons' hand movements with standard surgical tools, but on a smaller scale. The system also filters tremor and magnifies the force feedback surgeons receive, so they can get a better feel for the fragile and minute structures they are working on. The system is at an early stage, and animal tests show that dexterity and precision still need improving. But Mr Garcia says that if they can overcome these problems, clinical applications could be only three to five years away. Another way of tackling the human limitations to surgery is by developing intelligent tools. The Centre for Medical Robotics and Computer-Assisted Surgery at Carnegie Mellon University in Pittsburgh is developing a tool for eye microsurgery that can filter tremor, jerk and low-frequency wander.

## Beating heart

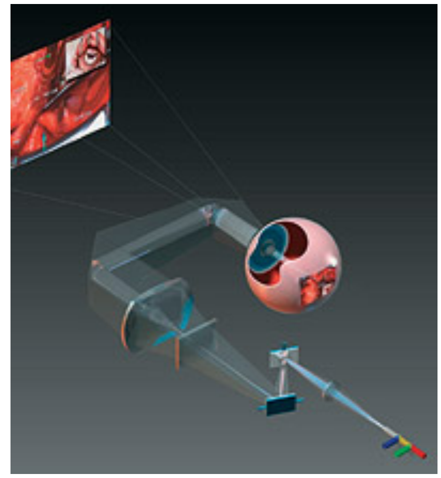
Surgery on beating hearts is also beginning to look possible. At the University of Tokyo, Yoshihiko Nakamura and Kosuke Kishi are working on a system that creates a stabilised image of a beating heart and a tool that translates surgical manoeuvres to compensate for the movement of the heartbeat. The principle is simple. Say someone were to wave a printed article from side to side in front of your eyes, one of the ways for you to read the now-blurred image would be to move your head in synchrony with the movement. The image on the page would then appear to be static. The camera developed by Dr Nakamura and Dr Kishi does exactly this, by tracking heart movements.

Image stabilisation has been combined with a slave robotic surgical instrument that compensates exactly for the movement of the heart. When the surgeon wants to make a small downward incision, the slave robot makes the movement—plus whatever extra amount the robot calculates is needed to compensate for the movement of the heart. On the monitor, what the surgeon sees is a stable image of the heart and the instrument. Meanwhile, the robot is making rhythmic motions like a conductor keeping time to the music. Dr Nakamura says the system's performance is promising. And if tests on animals work, it is of potential use in minimally invasive coronary-bypass surgery—a difficult, highly skilled, but desirable technique for reducing patient damage during surgery.

## The guiding hand

Imaging—such as ultrasonic scans, computed tomography (CT), magnetic resonance imaging (MRI) and fluoroscopy—allows surgeons to visualise and plan surgery accurately, leading to a decline in exploratory surgery. By combining imaging during surgery with robotic assistance, it is hoped that incredible precision will be possible on areas of the body which are normally difficult to get at. At least two separate teams, one at Georgetown University Medical Centre in Washington, DC, and another at the Fraunhofer Institute for Biomedical Engineering in Saint Ingbert, Germany, are attempting to develop a system which uses robotics and image guidance to place needles precisely in the spine. That requires movements accurate to a fraction of a millimetre. This year, the Georgetown team is to start clinical trials of its robotic needle.

A group at the Applied Physics Laboratory at the University of Washington, Seattle, has ideas for developing its portable ultrasound unit. This is already a huge (and commercial) advance over existing fridge-sized ultrasound units, and means that diagnosis of all kinds of internal injuries can be taken into the field. The group is working on a way of making a unit that will both see, and then treat, internal bleeding. The prototype has added “high-intensity focused ultrasound” (HIFU) to the portable ultrasound detector. HIFU can rapidly heat small regions beneath the surface of the skin, and seal off areas of bleeding in a fraction of a second. The idea is to give patients enough time to reach hospital in cases when their injuries would otherwise cause them to bleed to death before they arrived.



Eyes to the future: retinal scanning displays draw an image directly on to the retina with a low-powered laserMicrovision

Further down the line is “field induced suspended animation”. Suspended animation is a type of hypothermia already employed during some specialised types of surgery. Cooling the body slows the metabolism, reducing the brain's need for oxygen. The technique is used during some types of cardiac and neurovascular surgery, when the patient's blood is taken out of the body to be oxygenated (a cardiopulmonary-bypass) and there is thus a risk of oxygen deprivation.

Lyn Yaffe of the IIT Research Institute in Rockville, Maryland, says that if the brain and heart, the critical organs, could be cooled in the field, it would be possible to preserve life in emergencies such as massive bleeding, shock and cardiac arrest, in which the blood flow is temporarily halted. Currently, teams are working on developing a system that relies on portable visualisation, image guidance and some automation to introduce cooling fluids into the aorta (the body's main artery) while vital signs are monitored. Researchers say that what sounded far-fetched until recently, now looks feasible, and could conceivably be in ambulances in five years.

## Sight for sore eyes

The growing use of imaging in medicine is creating a mountain of data, as well as the pile of pre-operative data, images and planning notes, that surgeons may wish to refer to during surgery. It is increasingly common for surgeons to have to turn away, or even move away, from a patient in the operating theatre to check details such as pictures taken before or during an operation. Many groups are working towards a solution of adding information to the surgeon's vision. This so-called “augmented reality” is a halfway house between virtual reality (VR) and, well, reality. Virtual reality is the use of computer modelling to enable a person to interact with an artificial (usually three-dimensional) environment. Augmented reality means augmenting a view of the real world with data and images, much like the head-up displays used by modern fighter pilots.

Charles Steiner and his colleagues at the Cleveland Clinic Foundation in Ohio are working on a “unified interface” for surgeons to allow them access to a patient's critical information during surgery. Although this could be presented on a TV monitor, they are planning to use a full-colour, head-mounted augmented reality display which, they predict, will be commercially available later this year. What is unusual about the display is that the image is beamed direct into the eye.


Microvision

Such virtual retinal displays were invented by researchers at the Human Interface Technology Laboratory at the University of Washington in 1991, and are being commercialised by Microvision in Bothell, Washington.

The beauty of a retinal scanning display (RSD) is that the image is drawn directly on to the retina of the eye by a low-powered laser scanning backwards and forwards. Because the laser moves so rapidly, the human visual system sees a complete and stable image. This system's biggest advantage is that because there is no external image, no fancy external display unit is needed. That has enabled Microvision to build a small head-mounted RSD unit that uses little power and gives an impressively wide 120° field of view. Many VR helmets give a narrow 25° view of the world, and are like watching a mini-TV down the end of a cardboard tube. More than twice this angle is needed to fill a person's normal field of vision.

And because the image in retinal scanning is not created on an external screen in the usual way, there are no picture elements, (“pixels”) to contend with. So the resolution of the image in the eye is not limited by the number of pixels used by a display screen, but depends simply on the precision of the laser light source.

Closest to production is the monocular, single-colour Nomad display that projects an image into a single eye—rather like the display worn, in real life, by pilots who fly certain military helicopters. The effect this has on vision is similar to the robot vision shown in the film "The Terminator", played by Arnold Schwarzenegger. The robot can see a glowing list of options displayed in its field of vision, superimposed on its view of the real world beyond.

Microvision expects to start shipping the single-eye of the Nomad display this summer. But surgeons are likely to wait for the full-colour, binocular version, which will be better for viewing medical images. Besides, seeing an image superimposed over a single eye can be more than a little disconcerting because of the "image rivalry" set up between the assisted and unassisted eyes. But, whether for one eye or two, an interesting advantage of RSD in medicine is that, coupled with a head-mounted video camera, such displays can give other people—specialists and medical students, for example—access to the primary surgeon's computer-enhanced viewpoint, even when the audience is in another building or another part of the world.

A unique feature of RSDs is that because they project an image on to the retina, they can be used equally well by people with eye defects such as short- or long-sight. In particular, they produce clearer-than-normal images for those who are affected by age-related defects of the eyes. Telesensory, a company based in Sunnyvale, California, that specialises in products for people with poor vision, has ordered ten Nomad units from Microvision for evaluation. The units currently cost $10,000 each, but this is expected to drop significantly once they are in full production. While the head-mounted display is rather bulky, Microvision expects that, within five years, the device will be little bigger than a pair of spectacles.

Augmented reality will allow surgeons to look at images and data during surgery, without having to turn away from the patientMicrovision

Whatever the system used to display it, most experts agree that augmented reality is going to be invaluable in delicate procedures—such as the removal of brain tumours—where the slightest slip could harm the patient. Here, a group at Wayne State University in Detroit, Michigan, is working with NASA on one of the trickiest of problems: correctly superimposing images of anatomical structures and brain tumours on to a camera's view of a surgical procedure.

## Teacher's pet

Experts agree that the use of virtual reality, augmented reality and other simulation techniques is going to pay huge dividends in training surgeons and dentists. One virtual-reality training system has even been developed to teach surgical trainees how to set up an operating room properly for different types of surgery—a real benefit, as operating theatres cost around $30 a minute to run. And many of the new VR training systems include devices such as scissors and drills which, like video games, provide force-feedback. Trainees can feel what it is like to puncture an abdomen with a needle, collect bone marrow for transplant (difficult for the surgeon and often painful for the patient) or even drill into healthy and diseased parts of a tooth. Trainees can practice as many times as they like, and get feedback and precise measurements of their skill.

Much of this medical technology is being driven, and paid for, by the armed forces. But the difficulties of working under combat conditions means that it is likely to be used first by civilians. In the near future, advances in medical simulation will most certainly improve the accuracy and success of different types of surgery.

Eventually, as robotic tools are improved and made smaller and more dextrous, difficult techniques—such as neurosurgery and whole limb transplants—will become routine. And entirely new kinds of surgery, including operations on fetuses, will be possible. Meanwhile, the growing digitisation of the blood-and-guts business will allow medical technology to become increasingly distributed. Coupled with the falling price of broadband communications, the new imaging technologies should usher in an era when telemedicine and the sharing of medical information, expert opinion and diagnosis is common.

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