Pictures that count

Digital photography is versatile, but it takes some doing to achieve quality, says s ananthanarayanan

THE pictures with the best clarity are still taken by the old photo-film process. This is because the number of separate points of dark or shade on the film depends only on the size of silver halide particles. With a large number of minute particles, the picture can be very *fine grained*. In digital photography, the sensors of light are tiny bits of photosensitive and semi-conducting material deposited on the *sensor chip*, each one being individually addressed. We are now able to reach very fine grain in this technology as well. But digital cameras still cannot equal photo-film, because in digital cameras each particle on the chip needs to be separately accessed and read.

Scientists at Duke and Arizona Universities and in Distant Focus Corporation, Illinois, report a prototype digital camera that gets around this limitation and takes pictures in gigapixels, or 1,000 times better than the megapixel resolution achieved so far. This amounts to managing great detail in digital form, which then permits electronic storage, copy and analysis with wide applications.

A photograph, unlike a diagram of something seen through a microscope, is smaller than the object photographed. Larger areas of the object then need to be represented in a smaller area in the picture. Clearly, there is a limit to how small these smaller areas can be and, hence, how many of them and the detail captured. In digital photography, the quality of a picture is measured in terms of "*pic*ture *el*ements", or *pixels*, into which the image is resolved. Typical values, in good quality cameras, are *six megapixels*, or six million elements. If there is an object that is one metre square, it consists of 1,000 mm x 1,000 mm, or a million square millimetres. The six megapixel photograph of this object then devotes six pixels to each square millimetre of the full size image. But if the object was 60 metres square, like the picture of a building, then there is only one pixel for every six square *centimetres*. Blowing up this picture would rapidly destroy the details of its features.

With photo-film, we are able to do much better than the equivalent of six megapixels. A frame of 35 mm film of ISO 100 speed, for instance, can be as good as 16 million pixels. Professional quality pictures can be as good as 80 megapixels and, with special lenses and larger film area, even 800 megapixels! But with digital pictures, it is not routine to improve the quality in the same way, of only getting finer grain or increasing the size of the capture area. Normal digital cameras work at one to 10 megapixels, with a camera lens diameter in millimetres. Getting from here to the 1,000 megapixel, or the gigapixel range would call for both a lens diameter in centimetres as well as great complexity, not to mention cost, in building and dealing with the data from the array of a billion electronic sensors in the recording chip.

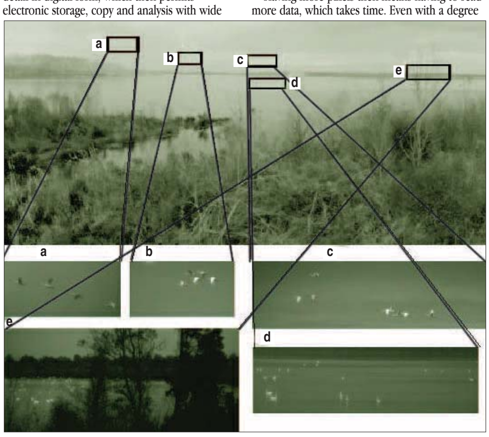
Parallel and series

Apart from finer grain being fairly cheap in the old photo-film process, the main advantage is that each speck of chemical in the film is independent of other specks and all the specks record the image at the same time, without any special arrangements. The recording of light or shade, at each point resolved by the film, is a *parallel process*. This is not the case with digital photography. Here, while all pixels are illuminated at the same time, the image is captured by individually reading the light or shade at each pixel and recording the data in computer media, like a flash drive or a hard disk. In going from pixel to pixel, it is a *serial process*.

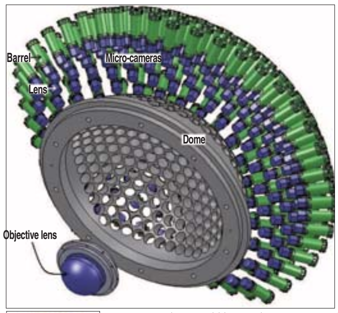
Having more pixels then means having to read more data, which takes time. Even with a degree of parallel reading, with buffering to enable recording, reading a million pixels is a substantial task of data management. Working at 16 megapixels is then in the very expensive, professional plane and reaching a gigapixel (1,000 megapixels) has remained out of reach. What the team of scientists in the work based in Duke University has done is to use a 1.6 cm lens and capture the image with 98 separate sensor arrays, each capable of 14 megapixels. The result is that that gigapixel image management is reduced to managing multiple megapixel images, which is more tractable. The work was part of a US defence department project to create an array of micro-cameras to scale into one to 100 gigapixel cameras, for different applications.

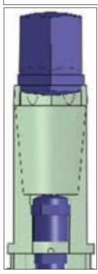
Using micro-cameras in tandem is like using microprocessors to work in parallel. And as with parallel computing, in photography there are issues of manner of image capture, materials, networking, data processing architecture, to achieve the trade-off between granularity and performance. Thus, in resolving elements that run into billions, with arrays of as many detectors, there have been different designs — for high altitude surveillance and for photography in astronomy. There could be an array of separate, narrow field cameras with their own lenses, or a single main lens with cameras arrayed in its curved focal plane.

Using digital techniques derived from feature film visual effects, images can be created at resolutions of up to 150,000 pixels wide, far surpassing any large format film standards used in photography. The use of this gigapixel imagery can be far-ranging, from use in producing visual effects in feature films, to helping educate the public in national parks. Delivery options range from interactive web or kiosk displays allowing for deep exploration of the images to large exhibition prints containg detail rarely seen at a large scale. Gigapixel photography is a new, highly immersive medium where the viewer can locate a myriad of life moments within a single image, yielding a deeper interaction with a single image than previously seen.



Detail captured in the high resolution photograph of Pungo Lake.





Micro-camera detail

Aware-2

The Duke University prototype, called Aware-2, uses a single objective lens and micro-cameras, the lens of each of which is the equivalent of the eyepiece of a telescope. The Focal radius is just over seven centimetres and the micro-cameras, which cover a curved focal plane, are arranged in an aluminium dome. The cameras are arranged in a geodesic pattern, to minimise irregularity and maximise overlap between camera fields. And the arrangement is able to take a picture every 18 seconds, or three pictures a minute. Aware-2 has achieved results of 50 gigapixels! The advantage of the design is seen as the scalability to higher pixel counts and easy operation as each micro-camera can be independently controlled. The system is ideal for low cost and high-resolution ground-based systems.

The potential for use of Aware-2 can be seen in a sample picture of Pungo Lake in North Carolina. The lake is part of the Pocosin Lakes National Wildlife Refuge, over 113,000 acres, and is home to more than 200 species of birds, over 40 species of mammals and more than 40 species of reptiles and amphibians. There is a great interest in mapping and recording animal and bird movements and populations. The 0.98 gigapixel snapshot shown in the picture records details of actual numbers of swans in flight and in the water at the instant the picture was taken.

A series of such pictures could enable automated analysis of bird movements that is inconceivable in the normal course. Other sample pictures are of crowded areas, building facades or even of the interior of a room. Gigapixel pictures, which are digital pictures, enable expanding specific areas in the picture to follow individuals in a crowd, specific skylights or openings in buildings or in the picture of the room, to visualise the pattern of a PCB placed on a shelf or even fingerprints on the furniture. There is similar application in high-resolution imaging of astronomical sightings, for later analysis at detail not available to the human eye.

Speaking the human eye, the idea of parallel processing is also used by this remarkable organ of optical processing. With a dimension of just two centimetres, the eye has about 130 million receptors of light, optimised for better resolved vision of parts of the image, or for better recognition of contrast or movement. But as we have seen, the limiting factor in systems that do more than just record, as in the photo-film, is the need to transmit data. It appears that the human eye is not just a receptor of light signals, it is an "intelligent" receptor, in the sense that it does some processing before it transmits what it has received to the proper areas of the brain. This is apparent because there can be 150 million receptors in the eye, but there are only about a million fibres in the optic nerve that carries information to the brain!

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A code breaker's life and legacy

Alan Turing gets rebooted, even if it's 50 years too late, writes jenny gilbert

THE popular attitude to very brainy people is that they must be, by definition, odd: insular, distracted, almost certainly on the autistic spectrum. To the London Science Museum's great credit, one outcome of its centenary tribute to the ultimately tragic maths genius, Alan Turing, has been to humanise him. You emerge from this excellent free exhibition — financed by Google — with the sense that some small redress has been made, albeit 50 years late, for the appallingly shabby treatment meted out to one of the greatest minds of the 20th century.

Turing's name summons up in most people a single image: that of the tweed-jacketed wartime codebreaker, beavering in top-secret isolation at Bletchley Park. There he was a cockerel among chickens — his workforce being largely Wrens — racing to unlock the Germans' encrypted radio messages, whose codes were fiendishly reset every day. Duly, the exhibition has on display three captured German Enigma machines (the modified typewriters used to encrypt the messages), a video about Bletchley Park and some smudgy photographs, made public for the first time. One shows scores of women at long benches, checking the day's "matches" on table-top versions of the vast, one-ton machines (long since melted down) developed by Turing to test millions of possible configurations at speed. While it's debatable whether Turing's effort won the Allies the war, it certainly hastened its end.

Alan Turing.

Less well known is the impact of his first major contribution to science, a paper written when he was 24 on an abstruse maths theory that shook the world of pure maths to its foundations. This we must take as read, for the exhibition glances off more fruitfully to explore influences on Turing's thinking — a working model of a "differential analyser" (precursor of the computer) constructed in Meccano, and a cybernetic tortoise developed to investigate animal brain function. Filmed nosing about the carpet, this resembles a novelty hands-free vacuum cleaner.

Turing not only pushed forward the arrival of the computer but also the link between maths, chemistry and biology in his work on "morphogenesis", studying patterns of growth in nature. This was quickly overshadowed by the discovery of DNA, but has since re-emerged as crucial in filling gaps of understanding: how, to put it crudely, a horse cell, say, grows into a horse.

The exhibition works on several levels, hands-on exhibits walking even technophobes through the basics of computer programming. Non-scientists will also be drawn to the moving letters penned by Turing as a schoolboy to the mother of a friend who died of TB (clearly the love of his life), and to the castrating oestrogen pills he shockingly chose instead of jail following his conviction for being gay, for which then crime he was arrested after reporting a burglary in 1951. The drugs worked: he lost his libido. But his intellect also lost its edge.

Geek lore would have it that the logo of the Apple corporation is a nod to Turing's suicide, on the assumption that the bitten apple found by his side was laced with the cyanide that killed him. Evidence here scotches that Snow White theory. This Great Briton died as he had lived – a quiet man of reason, not given to theatrical flourish.

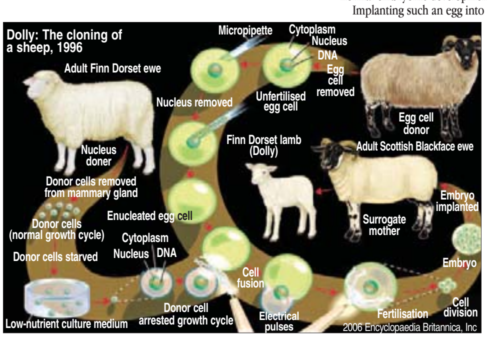
The Independent, London

A lamb with no father

Citing the process that produced Dolly the sheep, tapan kumar maitra says it is possible to envision a new form of farming in which cloning is utilised to create herds of identical animals that are used not for milk or meat but as sources of medically important human proteins and, perhaps, even tissues and organs

IN January 1996, who would have expected that the most dramatic scientific breakthrough of the year was comfortably resting in a barn? Later that year, Ian Wilmut made newspaper headlines around the world by introducing us to Dolly, the first animal ever cloned from an adult cell. Dolly was created by removing the nucleus from the cell of an adult sheep and transferring it into a different sheep's egg whose own nucleus had been removed. Although this nuclear transfer technique had been used before to clone animals, it had never been successful with cells taken from an adult. Early studies in frogs revealed that nuclei removed from embryonic cells or tadpoles could programme the development of a normal adult frog when transferred into a frog egg. However, when donor nuclei from adult cells were used, development never proceeded beyond the tadpole stage.

Wilmut suspected that these previous failures were caused by the active state of the chromatin in the donor cells. The trick, he said, was to make the DNA of the donor cells behave more like the inactive chromatin of a typical sperm cell that would normally fertilise an egg. His research team accomplished this by taking mammary gland cells from the udder of a six-year-old female sheep and starving them in culture to force them into the dormant, GO phase of the cell cycle. This caused many genes to turn off and ensured that the cells remained diploid (unlike cells in S or G2, which have replicated some or all of their DNA). When a nucleus from such donor cells was transplanted into an egg cell lacking a nucleus, it delivered the diploid amount of DNA in a condition that allowed the egg cytoplasm to reprogramme the DNA to support normal embryonic development.



Implanting such an egg into the uterus of another female sheep led to the birth of a lamb with no father — that is, a lamb whose cells had the same nuclear DNA as the cells of the six-year-old female sheep that provided the donor nucleus.

Within a few years of these pioneering experiments, similar techniques were used to clone other kinds of animals, including cattle, mice, goats and pigs. Does such technology have any practical value? One possibility is to insert potentially useful genes into the donor cells prior to transferring their nuclei into eggs for cloning. For example, investigators are using recombinant DNA techniques to introduce genes for medically important proteins such as human blood-clotting factors that are difficult to produce by other means.

This approach has already been used to clone sheep that produce milk containing the blood-clotting factor deficient in people with haemophilia.

Thus it is possible to envision, in the not-too-distant future, a new form of farming in which cloning is utilised to create herds of identical animals that are used not for milk or meat but as sources of medically important human proteins and, perhaps, even tissues and organs.

An even more dramatic application of cloning technology involves recent attempts to clone animals that are on the verge of extinction or have recently become extinct. But the most controversial possibility concerns the question of whether it would ever be ethical to attempt cloning with human cells. For the moment, it appears that producing healthy human clones would be exceedingly difficult. It took 277 attempts to produce Dolly, and many cloned animals that seem normal at birth develop health problems later and die prematurely. Dolly developed arthritis and lung disease and had to be euthanised at six years of age, well short of her normal lifespan.

In the face of such problems and nearly universal unease about the prospect of human cloning, many individuals have called for laws banning the use of such technology for duplicating humans. And yet some bioethicists have suggested that society might eventually find cloning acceptable under certain circumstances, such as cloning a dying child or helping an infertile couple to have a child. Although such discussions may make people uncomfortable, the rapid pace of scientific developments in this field makes it essential that society does not shy away from the debate.

Another potential application of the nuclear transfer technique is for producing human stem cells that could be used for replacing damaged cells in diseases such as diabetes, muscular dystrophy, Parkinson's or Alzheimer's. Scientists have already shown that it is possible to create embryonic stem cells that are genetically matched to an individual person by taking an adult cell nucleus from such an individual and transplanting it into an egg whose own nucleus has been removed. After dividing a few times in culture, the resulting mass of a few hundred cells contains stem cells that reproduce indefinitely and retain the capacity to form all the cell types of the body. However, the development of such technology is still in its early stages and many technical and ethical issues remain to be resolved before we find out whether stem cells can be used for treating human diseases.

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