Innovations Report

Jun 2006 Part I

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ICT

~~Logic from Chaos~~

New chips use chaos to produce potentially faster, more robust computing.

A reconfigurable chip developed by ChaoLogix in Gainesville, FL, makes it possible to morph a circuit from one type into another in an instant. Having the ability to effectively redesign chips an unlimited number of times after they've been manufactured could make chips faster and more robust. And, ultimately, it could bring down the cost of producing integrated circuits, by reducing the need to make expensive, custom-built chips.

The novel chips work by exploiting inherent "chaotic" behavior within the integrated circuits, enabling a single, simple circuit to behave like any kind of logic gate. Such a chip could be transformed, for example, from a graphics card into a memory chip and back again -- in just two computer clock cycles. "We have blurred the line between software and hardware," says William Ditto, chief technology officer of ChaoLogix, which was spun out of research at the University of Florida.

In many respects, the concept is similar to the development of software-defined radios [SDRs], says Ditto. These are devices that use a combination of custom-built integrated circuits and existing reconfigurable chips to provide a flexible mix of hardware and software, to make wireless devices that can adapt to operating at different radio frequencies and standards. But whereas SDRs can make only radio devices and consist of several chips designed to perform wireless functions, ChaoLogix's chips could, in theory, replace all of these chips in a single device.

Existing reconfigurable chips, called field programmable gate arrays (FPGAs), contain programmable interconnects that can be rewired to perform different functions. But FPGAs are relatively slow to reconfigure, typically taking milliseconds for each rewiring, or about one million times slower than ChaoLogix's chips. Because of this limitation, FPGAs tend to be reconfigured only once to form a single permanent circuit, usually as relatively cheap alternatives to building dedicated chips.

Rather than using programmable interconnects, ChaoLogix's approach is to use fixed circuits and instead exploit their inherent "noise" or chaos to make them produce different outputs without changing them. Normally, the circuits on a chip consist of arrangements of transistors designed to behave like a specific type of digital logic gate, such as a NAND and NOR gate. But if the inputs voltages to these circuits fall below certain thresholds, their behaviors become chaotic, producing undesirable outputs. ChaoLogix's trick is to put these chaotic states to use. They've designed a logic gate circuit that's capable of behaving like any kind of logic gate -- if the input voltages are just right. The common notion that chaotic systems are unstable and unpredictable is not accurate, says Ditto. Such systems can be extremely sensitive to changes, and it is possible to produce desired states reliably and reproducibly provided you ensure only minor changes are made to the inputs.

ChaoLogix has gotten to the stage where it can create any kind of gate from a small circuit of about 30 transistors. This circuit is then repeated across the chip, which can be transformed into different arrangements of logic gates in a single clock cycle, says Ditto. Despite having attracted the attention of both Intel and AMD, the technology is still in its early days, says Ditto. ChaoLogix is raising $2 million to produce a range of prototypes. But even if the company can gain only a tiny slice of the chip markets, it "will be huge," says Ditto.

Error-check breakthrough in quantum computing

An error-checking method that could prove crucial to the development of a practical quantum computer has been developed by US researchers.
Quantum computers process information in the form of quantum bits, or qubits. These act like the bits in conventional computers but, instead of existing in one of two states, a qubit can exist in both states simultaneously. This means a quantum computer can perform multiple calculations simultaneously. So far, only a handful of qubits have been used at a time to perform calculations in the laboratory. But if quantum computers can be scaled up, they should be able to perform incredibly tricky calculations in an instant.
Physicists at the University of California in Santa Barbra, US, have discovered a new way to check how much the information stored inside a quantum computer has decayed. This is an impressive feat since measuring the state of a qubit normally destroys its quantum properties.

There are several competing approaches to quantum computing, the most advanced of which involves using ions trapped in an electromagnetic field. An errorchecking method for this approach already exists but some researchers doubt it will ever successfully scale up to make a practical device. The error-checking method developed by the University of California team involves a competing approach, which experts say could have far greater potential to scale up.
In their set-up, a qubit is created using two superconducting metals separated by an insulating barrier. Passing a current through this component produces a qubit in the form of two energy levels in superposition, or both states simultaneously.Reducing the energy barrier used to maintain this state of superposition "collapses its quantum waveform" into one of the two energy levels. But Katz's team has found it can lower the energy barrier to a point just above the highest of the two energy levels, only partially collapsing the waveform. This is called a partial measurement.
Scanning the qubit using microwave radiation then reveals its state of superposition without making it collapse. In a functional quantum computer this could be used to confirm that a qubit can still be used for a quantum computation.
As an added bonus the hardware required can be manufactured with the technology used to make conventional computer chips. Katz's team plans to test its error-checking technique using a simple system involving just two qubits.

Journal reference: Science (vol 312 p 1498)

Nanocrystal Displays

QD Vision's Seth Coe-Sullivan is using quantum dots to make vibrant, flexible screens.

QD Vision's first display -- a monochromatic 32-by-64-pixel test bed for a technology Coe-Sullivan hopes will replace those used in today's high-definition TVs. Thin and flexible, the next-generation display will be easy to see in sunlight and less power hungry than the one in your current laptop, he says. It will also cover more of the visible color spectrum than current displays and produce such high-contrast images that today's flat-screen displays will look dull and washed out by comparison.

At its heart are nanoparticles called quantum dots, nanoscale semiconductor crystals. By altering the size of the particles, researchers can change the color they emit: for example, a six-nanometer-diameter particle would glow red, while another of the same material but only two nanometers wide would glow blue.

Where these particles really shine is in the purity of the colors they emit. Displays create millions of colors from a palette of just three: each pixel is made of a red, a green, and a blue subpixel, and varying their relative intensities varies the pixel's apparent color. In LCDs and organic light-emitting devices (OLEDs), a new kind of display, the subpixel colors are impure. The red, for example, while made mostly of red light, also contains smaller amounts of other colors. With quantum dots, however, the red subpixel emits only red. This purity means quantum dot-based displays have more-saturated color than LCDs, OLEDs, and even bulky cathode-ray tubes (CRTs), which are still prized for their excellent color rendition. What's more, Coe-Sullivan says, the range of colors possible in a quantum dot display is 30 percent greater than in CRTs.

Perhaps what is most exciting about quantum dot LEDs (QD-LEDs) is that they use much less power than LCDs. In LCDs, a backlight illuminates every pixel on the screen. Dark pixels are simply blocking this light, in effect wasting energy. In part because quantum dots emit light rather than filtering it, a QD-LED display could potentially use one-30th the power of an LCD.

And there's another benefit to not having a backlight. Because in LCDs the dark pixels don't block light perfectly the "black" pixels on LCDs are really just dark grey. With quantum dots, on the other hand, black pixels emit no light. "What makes the picture crisp and really jump out at you is that the black is really, really dark,".

Semiconductors slow light

Chris Phillips of Imperial College in London and co-workers have found a new way to apply the brakes to light: they have shown that light passing through a sandwich of wafer-thin films of semiconductors can be slowed to less than 1/40th of its speed in empty space. And the researchers think that ultimately their semiconductor sandwiches could bring light to a complete standstill.

This kind of manipulation of the speed of light could be useful in schemes for processing information in the form of light pulses, rather than the electrical currents of conventional silicon-chip electronics. So-called optical information technology is already the standard means of transmitting information over large distances, by sending light down optical fibres; but if signals encoded in light particles (photons) can also be shunted around 'photonic circuits', equivalent to today's microelectronic circuits, that might make information technologies faster and more powerful. Controlling the speed of light in such circuits could provide a way of synchronizing the signals, and even of storing information in 'frozen photons'. Devices that manipulate photons could also be used to create super-powerful quantum computers, which use the laws of quantum physics to perform calculations much more efficiently than today's supercomputers.

Making 'slow light' has been done before. Now Phillips and colleagues have found how to make 'designer' slow-light materials from the kind of semiconductors routinely used by microelectronic engineers.
Light generally propagates through a material by bouncing between its atoms: each photon, a packet of oscillating electrical and magnetic fields, interacts with the electrons in the atoms in a way that is described by quantum theory. Exotic 'quantum optical' effects such as slow light can be created by using laser beams to alter the atoms' electronic states and thus to tamper with their interactions with photons, in effect making the photons dally longer with each interaction. In a slab of semiconducting material such as silicon, the electronic states are too smeared out to permit this kind of fine-tuning. But in very narrow films of semiconductor, just a few nanometres thick, the electronic states are more sharply defined, and they can be adjusted by altering the film's thickness. Such thin slices are called quantum wells, and in effect they act like 'artificial atoms'.

Phillips and colleagues have shown that stacks of quantum wells made from the semiconductors indium gallium arsenide and aluminium indium arsenide have electronic states that can be tailored to manifest quantum-optical phenomena such as slow light. The layered films also display an unusual effect called 'gain without inversion', which enables a light signal to be amplified - the basic requirement for generating laser light - without first having to create the preponderance of high-energy electronic states required in conventional lasers.

Source: Institute of Physics

Researchers Build An Ultrasound Version Of The Laser

Researchers at the University of Illinois at Urbana-Champaign and at the University of Missouri at Rolla have built an ultrasound analogue of the laser, called ***uaser*** - for ultrasound amplification by stimulated emission of radiation.
The instrument produces ultrasonic waves that are coherent and of one frequency, and could be used to study laser dynamics and detect subtle changes, such as phase changes, in modern materials.

To make a uaser the team mounted a number of piezoelectric auto-oscillators to a block of aluminum, which serves as an elastic, acoustic body. When an external acoustic source is applied to the body, the oscillators synchronize to its tone. In the absence of an external source, the tiny ultrasonic transducers become locked to one another by virtue of their mutual access to the same acoustic system.
"The phases must be correct also. By carefully designing the transducers, we can assure the correct phases and produce stimulated emission. As a result, the power output scales with the square of the number of oscillators." Weaver, lead author of the research, says
The uaser more closely resembles a "random laser" than it does a conventional, highly directional laser. "In principle, however, there is no reason why we shouldn’t be able to design a uaser to generate a narrow, highly directional beam."

Optical lasers are useful because of their coherent emission, high intensity and rapid switching. These features are of little value in acoustics, where coherence is the rule and not the exception, intensity is limited by available power, and maximum switching speeds are limited by moderate frequencies.
Nevertheless, uasers may be useful. With their longer wavelengths and more convenient frequencies, uasers could prove useful for modeling and studying laser dynamics. They could also serve as highly sensitive scientific tools for measuring the elastic properties and phase changes of modern materials, such as thin films or high-temperature superconductors.
"Uasers can produce an ultrasonic version of acoustical feedback - an ultrasonic howl similar to the squeal created when a microphone is placed too close to a speaker," Weaver said. "By slowly changing the temperature while monitoring the ultrasonic feedback frequency, we could precisely measure the phase change in various materials."

Touch-sensitive 'skin' will give robots the sense they lack

Robots are one step closer to having a human sense of touch, thanks to a thin, flexible film that mimics the sensitivity of a human finger. The device may become useful in the next generation of robots and in automated tools used for microsurgery.
Touch is one of the first senses that humans develop, but because of its complexity it has been one of the last to be tackled by robotics. Touch has to relay information about the surface of an object, and also the amount of pressure needed in order to grasp it.
Previous touch sensors have had big problems with rigidity and durability. When constructed out of hard materials such as silicon, they were not able to contour to the robotic 'hand', while the daily wear and tear of touching also tended to bend and scratch the delicate materials. Robots clearly need something "more like human skin," says Ravi Saraf from the University of Nebraska "And we're getting there."
Saraf and his colleagues unveil their new sensor film in this week's Science.

The film is about 100 nanometres (100 x 10-9 metres) thick, roughly 1,000 times thinner than standard office paper. It is built like a sandwich of alternating layers of gold and cadmium sulphide nanoparticles, each separated by insulating polymer sheets just 2 or 3 nanometres thick.
The whole device is hooked up to electrodes that allow a current to flow through the film.
When pressed onto a surface, the stress distorts the layers so that electrons can more easily hop across the insulating polymer layers and hit the cadmium sulphide particles. This makes the particles glow — the greater the stress, the more light they emit. A camera then measures the strength of the glow, which relates directly to the pressure felt by different parts of the film.
The sensor can detect tiny surface details with a pressure of 9 kilopascals, a pressure similar to that used by human fingers to feel things and pick them up.
It can also distinguish a feature as small as 40 micrometres. Previous sensors could only detect in the millimeter range.

It may be some time before such sensors are used in the clinic, but for now, robotics researchers are surprised and excited about the device.

Microelectronics & Nanotech

Weaving a web of nanomaterials

Bioengineers at Tufts University in Massachusetts have combined spider silk with silica to make a super-strong nanomaterial that could be used in industrial and medical applications.
The engineered protein combines the flexibility and tensile strength of spider silk with the resilience of silica and has been used to form unique nanocomposite materials.
David Kaplan, Carole Perry and colleagues developed a fusion protein made of the spider silk and the silica-cored proteins of microscopic algae called diatoms. Silica can be difficult to produce in a factory, requiring high heat, but producing silica is relatively easy in diatoms, where it can be done at normal temperatures in water.
Taking advantage of silk's self-assembling properties, the researchers made films and fibres out of the resulting fusion proteins. The fused silica particles formed in a narrow range of sizes, unlike natural ones, which can have a broad range.
The ability to control such sizing in silica particles could be used for industrial and biomedical applications and new nanocomposites. The researchers say the technique may allow the production of other tough minerals, metals, and composites that are difficult to fabricate in industrial settings under ambient conditions.

Universal ink for microcontact printing

“Printing” on the micrometer scale is the technology of the future for the production of the electronic components used for such things as flat-screen monitors or (bio)sensors. Metal surfaces a few tens of square centimeters in size can already be structured without much experimental difficulty through a combination of microcontact printing and an etching process. Researchers are currently working to develop a simple production technology that is also broadly applicable for large surfaces. A team at Philips Research in Eindhoven in the Netherlands has now developed a universally applicable “ink” for microcontact printing.

The first step in microcontact printing is the production of an elastomeric malleable stamp by means of a mold. The stamp is then loaded with a special “ink” and is pressed onto the metal surface to be printed. The ink sticks to the metal surface and reproduces the microstructure of the stamp in a monomolecular layer. This monolayer acts as a corrosion-resistant mask in the subsequent etching process: the coated areas are not affected, whereas the metal in the uncoated areas is etched away, transferring the microstructure to the metal.
Each type of surface requires a different type of ink to stick to it: precious and coinage metals need ink molecules that can be bound by means of a metal–sulfur bond. Oxidic surfaces bind molecules with an acid functionality, such as carboxylic acids or phosphonic acids. Substrates that have different types of metals on their surface are thus not easy to structure. Also, identical structures cannot be transferred onto different substrates with the same stamp, because once loaded, the stamp cannot be “washed” off and loaded with a different ink easily—and production of a new stamp is the most expensive part of the process.

The researchers led by Dirk Burdinski have now developed a universally applicable ink. It consists of a mixture of both types of ink, sulfur-containing octadecanethiol and octadecanephosphonic acid. When polydimethylsiloxane stamps are loaded with this ink, both types of metals can be structured. The individual components of the ink are selectively transferred to their corresponding surface without interfering with each other. This universal ink is potentially also useful for the coating of microfluidic systems on diagnostic chips, as these often have inner wall structures made of different materials. Also electronic component blocks requiring good adherence of the protective coating to different components could thus first be homogenized at the surface, allowing for better sealing.

Researchers use laser beams to pluck nanowires

American researchers have used laser beams to pluck individual nanowires, making them vibrate like incredibly small, ultrasonic guitar strings.

The researchers from Boston University used laser beams to pluck nanowires 4 to 10 micrometers long and 250 nanometers in diameter. They said the technique could ultimately be used to make super-sensitive biological sensors capable of weighing individual viruses and biomolecules.

They said the frequency of a vibrating nanowire could be monitored and would change as a result of the tiny change in mass if anything stuck to it, offering a way to create extremely sensitive nanoscopic scales.

The researchers created light-sensitive silicon nanowires by coating them with a thin layer of chromium. The metal expands more rapidly than silicon in response to heating, which means the two-layer nanowire will bend when heated by pulses from an infrared laser.
Focusing pulses on to a 1-micrometer spot causes the wire to vibrate uniformly and to measure the size of the vibrations, the same spot is monitored using a green laser beam, the researchers said.

The strength of the vibrations increases as the nanowire approaches its resonant frequency. The researchers predict it should be possible to weigh a virus or a large biomolecule by attaching it to the wire and measuring changes to the resonant frequency

Life Sciences

Alzheimer's vaccine 'promising'

A potential DNA vaccine for Alzheimer's disease has produced promising results in mice.
In tests it helped cut levels of key amyloid proteins thought to cause the disease by up to 50% in some parts of the brain.
The Japanese study appears in the journal Proceedings of the National Academy of Sciences.

Over-production of amyloid proteins are thought to trigger symptoms of Alzheimer's by forming clumps that litter the brain. Previous studies have shown that it is possible to stimulate the immune system of mice to attack these plaques if they are immunised with amyloid protein.

This approach has been tested in preliminary trials on humans, but early results showed that the immune response was too strong, leading to damaging swelling of the brain, as well as plaque destruction.

New studies in man are currently underway that hope to mobilise the immune response in a less aggressive manner so that plaques are destroyed, but brain swelling is avoided. The latest approach, developed by a team at Tokyo Metropolitan Institute for Neuroscience, works by stimulating the body to produce small amounts of amyloid protein itself.

Mice are injected with naked DNA that codes for these proteins, rather than relying on a special virus to get it into the cell. This has the effect of producing a more gentle immune response, and importantly the DNA has also been designed so that it is not capable of replicating itself by incorporating itself into the human genome. In tests, the latest vaccine reduced the deposition of amyloid proteins by between 15.5% and 38.5% compared with untreated mice.
Deposition in specific areas of the brain - the cerebral cortex and hippocampus - was reduced 40%-50%.

The researchers suggest that DNA vaccines of the type they have produced could provide a cheap and effective strategy for treating Alzheimer's in future.

A New Method of Getting Drugs into the Brain

Focused ultrasound waves can make a tiny, temporary hole in the barrier surrounding the brain.

One of the biggest challenges in treating neurological conditions such as Parkinson's and Alzheimer's disease is finding safe and non-invasive ways to enable drugs to penetrate the brain's natural defense -- the blood-brain barrier. Now scientists have developed a way to temporarily open a very small part of that barrier using focused ultrasound. They hope this precise targeting will allow drugs to enter specific parts of the brain -- without exposing the rest of the brain and without damaging the barrier or surrounding neuronal tissue in the process.

Researchers from Columbia University used magnetic resonance imaging to reveal how the hippocampus can be targeted with focused ultrasound, without effecting the rest of the brain, in mice genetically engineered to have Alzheimer's disease.
Using ultrasound in this way is a "huge deal," says Al Kyle of Perfusion Technology, a startup medical research company that's trying to develop similar technology. There are ways to open the blood-brain barrier using drugs, he says, "but it's a really harsh treatment and requires several days in clinical care." With more than 11 million people suffering from neurological diseases in the United States alone, says Kyle, a safer and less severe option is needed.
Research by Kullervo Hynynen at the University of Toronto, who first demonstrated the potential use of ultrasound to open the barrier in 2001, has suggested that using ultrasound to open the blood-brain barrier is safe. But Hynynen is still cautious about the applications for this use of ultrasound. "There could be significant clinical potential," he says, but adds that it won't be certain until someone does it in humans.

The blood-brain barrier protects the brain, which is why it can be difficult for drugs to penetrate it. The barrier consists of endothelial cells that line the small blood vessels in the brain. These cells are tightly packed to create a wall between most parts of the brain and the rest of the circulatory system, blocking bacteria and all but the smallest molecules. Focused ultrasound works by directing sound waves toward a point in space. Individually, the waves are not powerful enough to affect the tissue, but when targeted, their collective intensity is much greater. When targeting the brain, though, the team at Columbia used much lower-intensity levels, similar to those applied in diagnostic ultrasound. While researchers don't know exactly how this technique is able to open the barrier, they say it's not through heating. Unlike tumor ablation --and this distinction is key – this technique appears to be reversible: the barrier closed up after about four hours. This is important because "the longer the blood-brain barrier is open, the longer you let nasty stuff in the brain."

The team at Columbia is now working on using higher-frequency ultrasound waves, which they believe will be able to penetrate human skulls.

Regrowing the Damaged Brain

Electrically stimulating the cerebral cortex could help stroke recovery.

In recent years, scientists have discovered that the brain has a remarkable capacity for self-repair. Hoping to take advantage of this ability, researchers have developed a technology to deliver electrical stimulation directly to brain tissue. The therapy, now being tested in large clinical trials, could boost the brain's repair mechanisms and improve recovery after stroke.

Studies in both laboratory animals and humans have shown that after stroke, neurons near the damaged tissue begin to reorganize themselves in an attempt to compensate for the injured areas. However, this healing ability can be hit or miss -- some patients regain the ability to walk or talk while others are left permanently disabled.

In many cases, patients can stimulate recovery through practice. Someone who has lost function in their left hand, for example, could practice various movements with that hand to boost the brain's innate repair mechanisms. "But in most cases, that neuroplasticity doesn't go far enough," says Alan Levy, CEO of Northstar Neuroscience, a medical device company based in Seattle, WA.
So Levy and collaborators designed a way to stimulate specific parts of the cortex to try to further enhance the brain's natural neuroplasticity. The technology has shown promise in preliminary human studies -- researchers found that patients receiving both rehabilitation therapy and stimulation improved 15 to 30 percent on standard tests of hand and arm function; while controls, who underwent only physical therapy, improved just 0 to 12 percent. Northstar is now sponsoring a larger clinical trial at 18 rehabilitation centers across the United States.

Experts caution that it's too soon to say how effective or broadly applicable the technology will be, though. "We need to see studies in larger groups to know if it's effective," says Douglas Katz, a neurologist at Boston University Medical School, "and under what circumstances it's effective, such as the location of stroke, the time after stroke [that the treatment is used], and how much stimulation is necessary." Adds Katz: "But I do think these techniques show a lot of promise."

The benefits may also depend on the severity of stroke. It's possible that this therapy will be effective only in patients with relatively mild impairments, says Randolph Nudo, director of the Landon Center on Aging at the University of Kansas Medical Center in Kansas City, who is studying the effects of the Northstar technology in animal models of stroke. People who have had a more severe stroke, and therefore have fewer neurons left to compensate for the damaged area, may not be able to benefit from stimulation.

Nudo and colleagues are running exhaustive animal studies to determine the most effective parameters for the cortical stimulation treatment, as well as if remote areas of the brain may be recruited to aid people with more severe stroke.

A Fundamentally New Approach To Improving Cancer Chemotherapy

A new strategy for getting anti-cancer drugs to kill cancer cells, without causing serious harm to normal cells in the body, is reported in the June issue of ACS Chemical Biology.

The approach, tested in laboratory experiments with several existing anti-cancer drugs, could offer substantial benefits for cancer patients, according to Jeffrey P. Kris at the University of Kansas at Lawrence , main author of the research..

The new approach would allow anticancer drugs to accumulate in both normal and malignant cells. The drugs, however, would be tweaked by giving them "basic" (i.e. alkaline) chemical properties. Normal cells simply isolate anti-cancer drugs with basic properties, greatly reducing the toxic effects. Cancer cells, in contrast, have an impaired ability to isolate basic substances, and get hit with a full blast of toxicity.

"It could allow cancer patients to tolerate higher and more effective doses of chemotherapy before normal cells are damaged to an extent that causes serious side effects and cessation of therapy," Krise said. "The approach is completely different from previous attempts that were designed to deliver drugs only to cancer cells and not normal cells." "The results of our studies should lead to the development of rationally designed molecules that are more selective and produce fewer side effects," Krise explained. "Importantly, this technology can also be used to modify existing drugs and increase their selectivity."