Staying on course

A gyroscope that relies on light beams has been miniaturised

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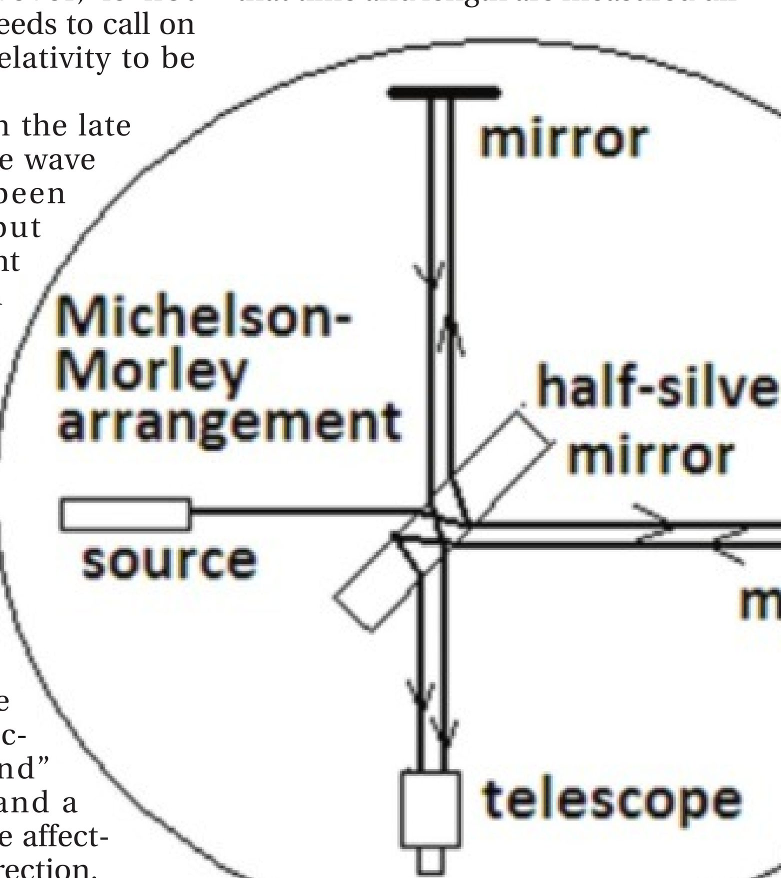
The unchanging stars of the night sky were surely the first device to tell directions. And then came the magnetic needle, which always pointed to the magnetic north. A further development was the gyroscope, which was like a spinning top, and could hold a direction in places where other methods could not be used. But the optical counterpart was a sophisticated sequel with a range of possibilities.

Parham P Khial, Alexander D White and Ali Hajimiri, of the department of electrical engineering, California Institute of Technology, describe in the journal, *Nature Photonics*, a strategy that improves on the current, state-of-the-art, optical gyroscope. The new version, integrated into a nano-sized device, 500 times smaller, works with 30 times greater sensitivity.

The conventional, mechanical gyroscope works on the principle of conservation of momentum. We know that the heavier an object, the more difficult it is to change its path, once it has got moving. The effect is more pronounced with spinning objects, which pack spinning energy within a small space, and they hold on to the axis of spin. The spinning top is an example — the force of gravity is not able to bring it down, unlike a stationary top, which would just topple.

The gyroscope is a similar, heavy, spinning object, mounted on swivelled bearings, so that it keeps its direction even while a vehicle in which it is mounted should twist and turn. It is better than the magnetic compass, as it is not affected by stray magnetic fields and then, it holds direction in three dimensions. The disadvantage is that it needs precision fabrication and is bulky. The optical gyroscope is more hardy, more accurate, can be integrated with computers and it can be miniaturised. Its principle of its working, that any state of rotation would affect the path of opposing beams of light, however, is not straight-forward and needs to call on Einstein's Theory of Relativity to be understood.

The story starts in the late 19th century, when the wave theory of light had been firmly established, but with the concept of light consisting of waves in an all pervading substance, known as "aether". Then, Albert A Michelson and Edward Morley, in 1887, carried out a celebrated experiment to detect the "aether", if there was one. The principle was that as the Earth was hurtling through space at a speed of 30 km a second, an "aether wind" should be blowing, and a beam of light should be affected, depending on its direction.



A beam of light was hence split into two, using a "half silvered" mirror, and two beams went on to-and-fro trips along paths at right angles. One path was along the direction of Earth's motion and the other was across the direction of motion. When the waves of light were recombined, the waves would be "in step" if they had travelled the same distance, or "out of step" if there was a difference in the distance. This state of being "in step" would be indicated by a pattern, called an "interference pattern", when the combined beams were viewed. And whatever the state of the pattern, it should change as the apparatus was turned around till the two arms exchanged places. The experiment did not reveal any change — a celebrated, negative result, which proved there was no "aether wind". The result had the important implication that although the two arms of the equipment — the Michelson's Interferometer — were in motion, the speed of light was the same in both directions. This led to a "correction factor", to explain the result, and then the Theory of Relativity, which builds on the constancy of the speed of light, to show that time and length are measured differently by observers in relative motion, the equivalence of mass and energy, and much else.

In the meantime a French scientist called Georges Sagnac carried out another experiment, which seemed to indicate there was, in fact, an "aether wind". In Sagnac's experiment, the two beams did not traverse separate paths, but they went round the same, circular path, but in the opposite direction. The circular path was then set to rotate, so that one half the light beam followed the sense of rotation, and hence traversed a longer path, while the other half traversed a shorter path. This time, the two halves of the beam did show interference when they were combined. It seemed to show that "aether" did exist. By the time this experiment was conducted, however, it had been shown, in theory, that there would be an interference pattern when the arrangement was rotated, as opposed to "translated" as in the Michelson-Morley experiment, with no need for an "aether" and quite in keeping with the theory of relativity.

The positive result, however, was the discovery of the Sagnac effect, that opposing beams of light in a rotating, circular path, take different times to go round. This led to the development of methods to detect rotation with the help of light beams, and the era of the optical gyroscopes. The older, mechanical gyroscope has been improved, by reliance not on spinning masses but on oscillating masses and is now found on devices like cell phones, to indicate and measure changes in orientation. In comparison, the optical gyroscope, based on the Sagnac effect and using a multi-spiralled coil of glass fibre to accumulate the effect, is far more sensitive and versatile.

The limitation, however, is that if the device is to be made smaller, the effect of the signal, which needs to be captured, gets feebler. The smallest optical fibre gyroscopes are hence about the size of a golf ball. The nano-photonic gyroscope, which would be the most versatile for embedding in devices, is hence out of reach.

What the Caltech researchers have done is to overcome this limitation. The problem with the faint signal of smaller arrangements is that random noise, the effect of temperature variations, scattering and back reflections, which the two beams pick up, distort the interference pattern. The researchers note that these disturbances, however, have frequencies in thousandths of a second and can hence be ignored over time spans of millionths of a second.

With this in mind, the Caltech team created an arrangement, called reciprocal sensitivity enhancement, where the two halves of beam rapidly reverse roles. A beam moving clockwise hence starts to move anti-clockwise, while the other beam similarly switches from anti-clockwise to clockwise. In this process, the paper says, polarity of the desired signal is switched, but the noisy element remains the same, and can be suppressed.

Using silicon waveguides as the path of a laser for the beam, the arrangement can be built at the size of a grain of rice and its sensitivity in detecting the difference of the beams is the highest of nano-devices so far, the paper says.

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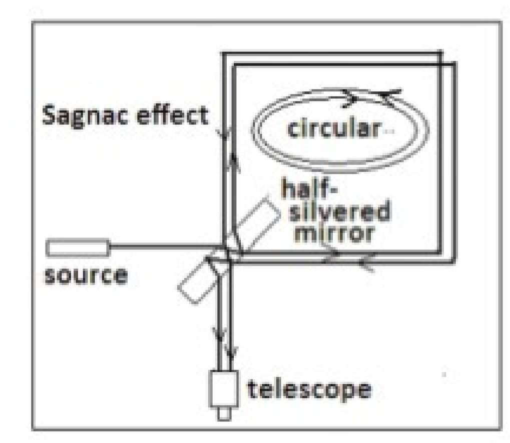
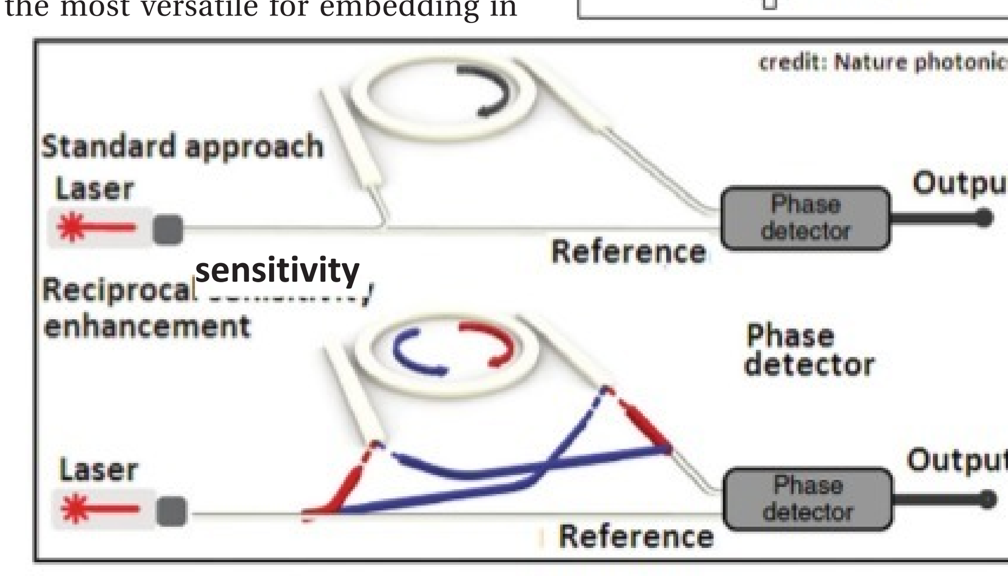




People plus machines

TERRENCE SEJNOWSKI

The future won't be made by either humans or machines alone — but by both, working together. Technologies modelled on how human brains work are already augmenting people's abilities, and will only get more influential as society gets used to these increasingly capable machines.

Technology optimists have envisioned a world with rising human productivity and quality of life as artificial intelligence systems take over life's drudgery and administrivia, benefiting everyone. Pessimists, on the other hand, have warned that these advances could come at great cost in lost jobs and disrupted lives. And fearmongers worry that AI might eventually make human beings obsolete.

However, people are not very good at imagining the future. Neither utopia nor doomsday is likely. In my new book, "The Deep Learning Revolution," my goal was to explain the past, present and future of this rapidly growing area of science and technology. My conclusion is that AI will make you smarter, but in ways that will surprise you.

Contrary to prevalent fears of obliteration as a species, Artificial Intelligence will only make humans smarter

Recognising patterns

Deep learning is the part of AI that has made the most progress in solving complex problems like identifying objects in images, recognising speech from multiple speakers and processing text the way people speak or write it. Deep learning has also proven useful for identifying patterns in the increasingly large data sets that are being generated from sensors, medical devices and scientific instruments.

The goal of this approach is to find ways a computer can represent the complexity of the world and generalise from previous experience — even if what's happening next isn't exactly the same as what happened before. Just as a person can identify that a specific animal she has never seen before is in fact a cat, deep learning algorithms can identify aspects of what might be called "catness" and extract those attributes from new images of cats.

The methods for deep learning are based on the same principles that power the human brain. For instance, the brain handles lots of data of various kinds in many processing units at the same time. Neurons have many connections to each other, and those links strengthen or weaken depending on how much they're used, establishing associations between sensory inputs and conceptual outputs.

The most successful deep learning network is based on 1960s research into the architecture of the visual cortex, a part of the brain that we use to see, and learning algorithms that were invented in the 1980s. Back then, computers were not yet fast enough to solve real-world problems. Now, though, they are.

In addition, learning networks have been layered on top of each other, creating webs of connections more closely resembling the hierarchy of layers found in the visual cortex. This is part of a convergence taking place between artificial and biological intelligence.

Deep learning in real life

Deep learning is already adding to human capabilities. If you use Google services to search the web, or use its apps to translate from one language to another or turn speech into text, technology has made you smarter or more effective. Recently on a trip to China, a friend spoke English into his Android phone, which translated it to spoken Chinese for a taxi driver — just like the universal translator on Star Trek.

These and many other systems are already at work, helping you in your daily life even if you're not aware of them. For instance, deep learning is beginning to take over the reading of X-ray images and photographs of skin lesions for cancer detection. Your local doctor will soon be able to spot problems that are evident today only to the best experts.

Even when you do know there's a machine involved, you might not understand the complexity of what they're actually doing — Behind Amazon's Alexa is a bevy of deep learning networks that recognise your request, sift through data to answer your questions and take actions on your behalf.

Advancing learning

Deep learning has been highly effective at solving pattern recognition problems, but to go beyond this requires other brain systems. When an animal is rewarded for an action, it is more likely to take similar actions in the future. Dopamine neurons in the basal ganglia of the brain report the difference between expected and received rewards, called reward prediction error, which is used to change the strengths of connections in the brain that predict future rewards.

Coupling this approach, called reinforcement learning, with deep learning can give computers the power to identify unexpected possibilities. By recognising a pattern and then responding to it in a way that yields rewards, machines might approach behaviours along the lines of what might be called human creativity. This coupled approach is how DeepMind developed a programme called AlphaGo, which in 2016 defeated grandmaster Lee Sedol and the following year beat the world Go champion, Ke Jie.

Games are not as messy as the real world, which is filled with shifting uncertainties. Massimo Vergassola at the University of California, San Diego, and I recently used reinforcement learning to teach a glider in the field how to soar like a bird in turbulent thermals. Sensors can be attached to actual birds to test whether they use the same cues and respond the same way.

Despite these successes, researchers do not yet fully understand how deep learning solves these problems. Of course, we don't know how the brain solves them either.

While the brain's inner workings may remain elusive, it is only a matter of time before researchers develop a theory of deep learning. The difference is that when studying computers, researchers have access to every connection and pattern of activity in the network. The pace of progress is rapid, with research papers appearing daily on *arXiv*. Surprising advances are eagerly anticipated this December at the Neural Information Processing Systems conference in Montreal, which sold out 8,000 tickets in 11 minutes, leaving 9,000 hopeful registrants on the waiting list.

There is a long way to go before computers achieve general human intelligence. The largest deep learning network today has only the power of a piece of human neural cortex the size of a rice grain. And we don't yet know how the brain dynamically organises interactions between larger brain areas.

Nature already has that level of integration, creating large-scale brain systems capable of operating all aspects of the human body while pondering deep questions and completing complex tasks. Ultimately, autonomous systems may become as complex, joining the myriad living creatures on our planet.

The writer is Francis Crick Professor and Director of the Computational Neurobiology Laboratory at Salk Institute for Biological Studies, and Distinguished Professor of Neurobiology, University of California San Diego. This article first appeared on www.theconversation.com

PLUS POINTS

Uncanny indeed

Nasa delighted the world when it announced it had found an uncannily rectangular iceberg floating in the Antarctic. And now it has revealed another one.

The scientists who took the picture that was shared around the world has revealed that he saw another iceberg on the same trip. Both pictures come from the IceBridge project, where Nasa flies planes over the polar ice to assess changes in the height and the state of the ice.

The new specimen is not quite as astonishingly flat and crisp as the iceberg that fascinated the world this week. But it has much of the same appeal, looking as if it is so out of place among the rest of ice and water surrounding it that there is something strange going on.

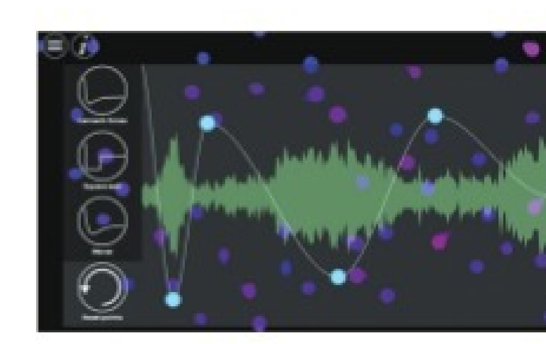
In the picture above, it can be seen just off the centre, hovering amid a set of much smaller and messier icebergs. The original slab can be seen just off in the left, almost obscured by the plane's engine and wing.

IceBridge senior support scientist Jeremy Harbeck, who took the pictures, said that he sees icebergs with such squared fairly often. But he had never seen one before that looked quite as clean as this, he said.

"I thought it was pretty interesting; I often see icebergs with relatively straight edges, but I've not really seen one before with two corners at such right angles like this one had," he said.

The Independent

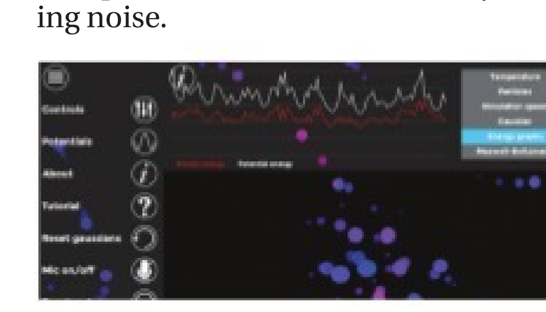
Microscopic movements



A new smartphone app that enables people to see how atoms and molecules move in the world around them in unprecedented detail has been developed by scientists at the University of Sheffield.

The app, developed by a team of scientists including Robert Shaw, a PhD student from the University's department of chemistry, gives people a chance to easily explore how atoms and molecules react to changes in the environment like never before. From watching crystals form at low temperatures to seeing particles bounding around under extreme heat, the app allows people to quickly simulate different environmental settings and instantly see the impact they have on the world at a microscopic level.

Named Argon, the app acts as a molecular dynamics simulator — a technique used by scientists to model the behaviour of atoms, molecules and large biological structures. The app even allows people to add areas of attraction or repulsion and control them by making noise.



Shaw, one of the PhD students who developed the app, said, "Some of the world's most important scientific discoveries were made by people who were experimenting and just exploring science in a way that was fun to them without really knowing what their work might lead to. This is what we're trying to inspire with the Argon app.

"We've designed the app to be as fun and easy to use as possible for people studying at all levels of chemistry. It can be used by high school pupils, university students who are studying chemistry at degree level or even people who just have a passing interest in science and are thinking about getting into chemistry for the first time." It can be used by teachers as part of their lesson plans and it has already received praise from lecturers who are planning to use it as part of their undergraduate teaching for chemistry students.

The Argon app is free and can be used on Apple, Windows and Linux devices. The team is currently developing an Android version, which will be available in the near future. To download the app, visit http://*www.argon-md.co.uk/*