Imaging See Around Corners

In addition to helping resolve many of the technical challenges of non-line-of-sight imaging, the technology, Velten notes, can be made to be both inexpensive and compact, meaning real-world applications are just a matter of time. [28]

Researchers in the Department of Physics of ETH Zurich have measured how electrons in so-called transition metals get redistributed within a fraction of an optical oscillation cycle. [27]

Insights from quantum physics have allowed engineers to incorporate components used in circuit boards, optical fibers, and control systems in new applications ranging from smartphones to advanced microprocessors. [26]

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The technology could allow for new capabilities in quantum computing, including modems that link together many quantum computers at different locations. [24]

A University of Oklahoma physicist, Alberto M. Marino, is developing quantum-enhanced sensors that could find their way into applications ranging from biomedical to chemical detection. [23]

A team of researchers from Shanghai Jiao Tong University and the University of Science and Technology of China has developed a chip that allows for two-dimensional quantum walks of single photons on a physical device. [22]

The physicists, Sally Shrapnel, Fabio Costa, and Gerard Milburn, at The University of Queensland in Australia, have published a paper on the new quantum probability rule in the New Journal of Physics. [21]

Probabilistic computing will allow future systems to comprehend and compute with uncertainties inherent in natural data, which will enable us to build computers capable of understanding, predicting and decision-making. [20]

For years, the people developing artificial intelligence drew inspiration from what was known about the human brain, and it has enjoyed a lot of success as a result. Now, AI is starting to return the favor. [19]

Scientists at the National Center for Supercomputing Applications (NCSA), located at the University of Illinois at Urbana-Champaign, have pioneered the use of GPU-accelerated deep learning for rapid detection and characterization of gravitational waves. [18]

Researchers from Queen Mary University of London have developed a mathematical model for the emergence of innovations. [17]

Quantum computers can be made to utilize effects such as quantum coherence and entanglement to accelerate machine learning. [16]

Neural networks learn how to carry out certain tasks by analyzing large amounts of data displayed to them. [15]

Who is the better experimentalist, a human or a robot? When it comes to exploring synthetic and crystallization conditions for inorganic gigantic molecules, actively learning machines are clearly ahead, as demonstrated by British Scientists in an experiment with polyoxometalates published in the journal Angewandte Chemie. [14]

Machine learning algorithms are designed to improve as they encounter more data, making them a versatile technology for understanding large sets of photos such as those accessible from Google Images. Elizabeth Holm, professor of materials science and engineering at Carnegie Mellon University, is leveraging this technology to better understand the enormous number of research images accumulated in the field of materials science. [13]

With the help of artificial intelligence, chemists from the University of Basel in Switzerland have computed the characteristics of about two million crystals made up of four chemical elements. The researchers were able to identify 90 previously unknown thermodynamically stable crystals that can be regarded as new materials. [12]

The artificial intelligence system's ability to set itself up quickly every morning and compensate for any overnight fluctuations would make this fragile technology much more useful for field measurements, said co-lead researcher Dr Michael Hush from UNSW ADFA. [11]

Quantum physicist Mario Krenn and his colleagues in the group of Anton Zeilinger from the Faculty of Physics at the University of Vienna and the Austrian Academy of Sciences have developed an algorithm which designs new useful quantum experiments. As the computer does not rely on human intuition, it finds novel unfamiliar solutions. [10]

Researchers at the University of Chicago's Institute for Molecular Engineering and the University of Konstanz have demonstrated the ability to generate a quantum logic operation, or rotation of the qubit, that - surprisingly—is intrinsically resilient to noise as well as to variations in the strength or duration of the control. Their achievement is *based on a geometric concept known as the Berry phase and is implemented through entirely optical means within a single electronic spin in diamond. [9]*

New research demonstrates that particles at the quantum level can in fact be seen as behaving something like billiard balls rolling along a table, and not merely as the probabilistic smears that the standard interpretation of quantum mechanics suggests. But there's a catch - the tracks the particles follow do not always behave as one would expect from "realistic" trajectories, but often in a fashion that has been termed "surrealistic." [8]

Quantum entanglement—which occurs when two or more particles are correlated in such a way that they can influence each other even across large distances—is not an all-or-nothing phenomenon, but occurs in various degrees. The more a quantum state is entangled with its partner, the better the states will perform in quantum information applications. Unfortunately, quantifying entanglement is a difficult process involving complex optimization problems that give even physicists headaches. [7]

A trio of physicists in Europe has come up with an idea that they believe would allow a person to actually witness entanglement. Valentina Caprara Vivoli, with the University of Geneva, Pavel Sekatski, with the University of Innsbruck and Nicolas Sangouard, with the University of Basel, have together written a paper describing a scenario where a human subject would be able to witness an instance of entanglement—they have uploaded it to the arXiv server for review by others. [6]

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the Wave-Particle Duality and the electron's spin also, building the Bridge between the Classical and Quantum Theories.

The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate and the Weak and Strong Interactions by the diffraction patterns. The Weak Interaction changes the diffraction patterns by moving the electric charge from one side to the other side of the diffraction pattern, which violates the CP and Time reversal symmetry.

The diffraction patterns and the locality of the self-maintaining electromagnetic potential explains also the Quantum Entanglement, giving it as a natural part of the relativistic quantum theory.

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Author: George Rajna

Preface

Physicists are continually looking for ways to unify the theory of relativity, which describes largescale phenomena, with quantum theory, which describes small-scale phenomena. In a new proposed experiment in this area, two toaster-sized "nanosatellites" carrying entangled condensates orbit around the Earth, until one of them moves to a different orbit with different gravitational field strength. As a result of the change in gravity, the entanglement between the condensates is predicted to degrade by up to 20%. Experimentally testing the proposal may be possible in the near future. [5]

Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently – instead, a quantum state may be given for the system as a whole. [4]

I think that we have a simple bridge between the classical and quantum mechanics by understanding the Heisenberg Uncertainty Relations. It makes clear that the particles are not point like but have a dx and dp uncertainty.

Lessons of conventional imaging let scientists see around corners

Along with flying and invisibility, high on the list of every child's aspirational superpowers is the ability to see through or around walls or other visual obstacles. That capability is now a big step closer to reality as scientists from the University of Wisconsin-Madison and the Universidad de Zaragoza in Spain, drawing on the lessons of classical optics, have shown that it is possible to image complex hidden scenes using a projected "virtual camera" to see around barriers.

The technology is described in a report today (Aug. 5, 2019) in the journal *Nature*. Once perfected, it could be used in a wide range of applications, from defense and disaster relief to manufacturing and medical imaging. The work has been funded largely by the military through the U.S. Defense Department's Advanced Research Projects Agency (DARPA) and by NASA, which envisions the technology as a potential way to peer inside hidden caves on the moon and Mars.

Technologies to achieve what scientists call "non-line-of-sight imaging" have been in development for years, but technical challenges have limited them to fuzzy pictures of simple scenes. Challenges that could be overcome by the new approach include imaging far more complex hidden scenes, seeing around multiple corners and taking video.

"This non-line-of sight imaging has been around for a while," says Andreas Velten, a professor of biostatistics and medical informatics in the UW School of Medicine and Public Health and the senior author of the new *Nature* study. "There have been a lot of different approaches to it."

The basic idea of non-line of-sight imaging, Velten says, revolves around the use of indirect, reflected light, a light echo of sorts, to capture images of a hidden scene. Photons from thousands of pulses of laser light are reflected off a wall or another surface to an obscured scene and the reflected, diffused light bounces back to sensors connected to a camera. The recaptured light particles or photons are then used to digitally reconstruct the hidden scene in three dimensions.

"We send light pulses to a surface and see the light coming back, and from that we can see what's in the hidden scene," Velten explains.

University of Wisconsin Researchers do non-line of-sight imaging by using indirect, reflected light, a light echo of sorts, to capture images of a hidden scene. Credit: UW-Madison

Recent work by other research groups has focused on improving the quality of scene regeneration under controlled conditions using small scenes with single objects. The work presented in the new *Nature* report goes beyond simple scenes and addresses the primary limitations to existing non-line-of-sight imaging technology, including varying material qualities of the walls and surfaces of the hidden objects, large variations in brightness of different hidden objects, complex inter-reflection of light between objects in a hidden scene, and the massive amounts of noisy data used to reconstruct larger scenes.

Together, those challenges have stymied practical applications of emerging non-line-of-sight imaging systems.

Velten and his colleagues, including Diego Gutierrez of the Universidad de Zaragoza, turned the problem around, looking at it through a more conventional prism by applying the same math used to interpret images taken with conventional line-of-sight imaging systems. The new method surmounts the use of a single reconstruction algorithm and describes a new class of imaging algorithms that share unique advantages.

Conventional systems, notes Gutierrez, interpret diffracted light as waves, which can be shaped into images by applying well known mathematical transformations to the light waves propagating through the imaging system.

In the case of non-line-of-sight imaging, the challenge of imaging a hidden scene, says Velten, is resolved by reformulating the non-line-of-sight imaging problem as a wave diffraction problem and then using well-known mathematical transforms from other imaging systems to interpret the waves and reconstruct an image of a hidden scene. By doing this, the new method turns any diffuse wall into a virtual camera.

"What we did was express the problem using waves," says Velten, who also holds faculty appointments in UW-Madison's Department of Electrical and Computer Engineering and the Department of Biostatistics and Medical Informatics, and is affiliated with the Morgridge Institute for Research and the UW-Madison Laboratory for Optical and Computational Instrumentation. "The systems have the same underlying math, but we found that our reconstruction is surprisingly robust, even using really bad data. You can do it with fewer photons."

On July 11, 2019, UW graduate students (left to right) Xiaochun Liu, Ji-Hyun Nam and Toan Le work with assistant professor and principal investigator Andreas Velten (right) in the Computational Optics lab inside the Medical Sciences Building at the University of Wisconsin-Madison on a project designed to create non-line-of-sight images using reflected laser light. Credit: Bryce Richter /UW-Madison

Using the new approach, Velten's team showed that hidden scenes can be imaged despite the challenges of scene complexity, differences in reflector materials, scattered ambient light and varying depths of field for the objects that make up a scene.

The ability to essentially project a camera from one surface to another suggests that the technology can be developed to a point where it is possible to see around multiple corners: "This should allow us to image around an arbitrary number of corners," says Velten. "To do so, light has to undergo multiple reflections and the problem is how do you separate the light coming from different surfaces? This 'virtual camera' can do that. That's the reason for the complex scene: there are multiple bounces going on and the complexity of the scene we image is greater than what's been done before."

According to Velten, the technique can be applied to create virtual projected versions of any imaging system, even video cameras that capture the propagation of light through the hidden scene. Velten's team, in fact, used the technique to create a video of light transport in the hidden scene, enabling visualization of light bouncing up to four or five times, which, according to the Wisconsin scientist, can be the basis for cameras to see around more than one corner.

The technology could be further and more dramatically improved if arrays of sensors can be devised to capture the light reflected from a hidden scene. The experiments described in the new *Nature* paper depended on just a single detector.

In medicine, the technology holds promise for things like robotic surgery. Now, the surgeon's field of view is restricted when doing sensitive procedures on the eye, for example, and the technique developed by Velten's team could provide a more complete picture of what's going on around a procedure.

In addition to helping resolve many of the technical challenges of non-line-of-sight imaging, the technology, Velten notes, can be made to be both inexpensive and compact, meaning real-world applications are just a matter of time. [28]

Physicists measure how electrons in transition metals get redistributed within fraction of optical oscillation cycle

Researchers in the Department of Physics of ETH Zurich have measured how electrons in so-called transition metals get redistributed within a fraction of an optical oscillation cycle. They observed the electrons getting concentrated around the metal atoms within less than a femtosecond. This regrouping might influence important macroscopic properties of these compounds, such as electrical conductivity, magnetization or optical characteristics. The work therefore suggests a route to controlling these properties on extremely fast time scales.

The distribution of electrons in transition metals, which represent a large part of the periodic table of chemical elements, is responsible for many of their interesting properties used in applications. The magnetic properties of some of the members of this group of materials are, for example, exploited for data storage, whereas others exhibit excellent electrical conductivity. Transition metals also have a decisive role for novel materials with more exotic behaviour that results from strong interactions between the electrons. Such materials are promising candidates for a wide range of future applications.

In their experiment, whose results they report in a paper published today in *Nature Physics*, Mikhail Volkov and colleagues in the Ultrafast Laser Physics group of Prof. Ursula Keller exposed thin foils of the transition metals titanium and zirconium to short laser pulses. They observed the redistribution of the electrons by recording the resulting changes in optical properties of the metals in the extreme ultraviolet (XUV) domain. In order to be able to follow the induced changes with sufficient temporal resolution, XUV pulses with a duration of only few hundred attoseconds (10^{-18} s) were employed in the measurement. By comparing the experimental results with theoretical models, developed by the group of Prof. Angel Rubio at the Max Planck Institute for the Structure and Dynamics of Matter in Hamburg, the researchers established that the change unfolding in less than a femtosecond (10^{-15} s) is due to a modification of the electron localization in the vicinity of the metal atoms. The theory also predicts that in transition metals with more strongly filled outer electron shells an opposite motion—that is, a delocalization of the electrons—is to be expected.

Ultrafast control of material properties

The electron distribution defines the microscopic electric fields inside a material, which do not only hold a solid together but also to a large extent determine its macroscopic properties. By changing the distribution of electrons, one can thus steer the characteristics of a material as well. The experiment of Volkov et al. demonstrates that this is possible on time scales that are considerably shorter than the oscillation cycle of visible light (around two femtoseconds). Even more important is the finding that the time scales are much shorter than the so-called thermalization time, which is the time within which the electrons would wash out the effects of an external control of the electron distribution through collisions between themselves and with the crystal lattice.

Initial surprise

Initially, it came as a surprise that the laser pulse would lead to an increased electron localization in titanium and zirconium. A general trend in nature is that if bound electrons are provided with more energy, they will become less localized. The theoretical analysis, which supports the experimental observations, showed that the increased localization of the electron density is a net effect resulting from the stronger filling of the characteristic partially filled d-orbitals of the transition-metal atoms. For transition metals that have d-orbitals which are already more than half filled (that is, elements more towards the right in the periodic table), the net effect is to the opposite and corresponds to a delocalization of the electronic density.

Towards faster electronic components

While the result now reported is of fundamental nature, the experiments demonstrate the possibility of a very fast modification of material properties. Such modulations are used in electronics and opto-electronics for the processing of electronic signals or the transmission of data. While present components process signal streams with frequencies in the gigahertz (10^9Hz) range, the results of Volkov and co-workers indicate the possibility of signal processing at petahertz frequencies (10^{15} Hz). These rather fundamental findings might therefore inform the development of the next generations of ever-faster components, and through this indirectly find their way into our daily life. [27]

Unique electrical properties in quantum materials can be controlled using light

Insights from quantum physics have allowed engineers to incorporate components used in circuit boards, optical fibers, and control systems in new applications ranging from smartphones to advanced microprocessors. But, even with significant progress made in recent years, researchers are still looking for new and better ways to control the uniquely powerful electronic properties of quantum materials.

A new study from Penn researchers found that Weyl semimetals, a class of quantum materials, have bulk quantum states whose electrical properties can be controlled using light. The project was led by Ritesh Agarwal and graduate student Zhurun Ji in the School of Engineering and Applied Science in collaboration with Charles Kane, Eugene Mele, and Andrew M. Rappe in the School of Arts and Sciences, along with Zheng Liu from Nanyang Technological University. Penn's Zachariah Addison, Gerui Liu, Wenjing Liu, and Heng Gao, and Nanyang's Peng Yu, also contributed to the work. Their findings were published in *Nature Materials*.

A hint of these unconventional photogalvanic properties, or the ability to generate electric current using light, was first reported by Agarwal in silicon. His group was able to control the movement of electrical current by changing the chirality, or the inherent symmetry of the arrangement of silicon atoms, on the surface of the material.

"At that time, we were also trying to understand the properties of topological insulators, but we could not prove that what we were seeing was coming from those unique surface states," Agarwal explains.

Then, while conducting new experiments on Weyl semimetals, where the unique quantum states exist in the bulk of the material, Agarwal and Ji got results that didn't match any theories that could explain how the electrical field was moving when activated by light. Instead of the electrical current flowing in a single direction, the current moved around the semimetal in a swirling circular pattern.

Agarwal and Ji turned to Kane and Mele to help develop a new theoretical framework that could explain what they were seeing. After conducting new, extremely thorough experiments to iteratively eliminate all other possible explanations, the physicists were able to narrow the possible explanations to a single theory related to the structure of the light beam.

"When you shine light on matter, it's natural to think about a beam of light as laterally uniform," says Mele. "What made these experiments work is that the beam has a boundary, and what made the current circulate had to do with its behavior at the edge of the beam."

Using this new theoretical framework, and incorporating Rappe's insights on the electron energy levels inside the material, Ji was able to confirm the unique circular movements of the electrical current. The scientists also found that the current's direction could be controlled by changing the light beam's structure, such as changing the direction of its polarization or the frequency of the photons.

"Previously, when people did optoelectronic measurements, they always assume that light is a plane wave. But we broke that limitation and demonstrated that not only light polarization but also the spatial dispersion of light can affect the light-matter interaction process," says Ji.

This work allows researchers to not only better observe quantum phenomena, but it provides a way to engineer and control unique quantum properties simply by changing light beam patterns. "The idea that the modulation of light's polarization and intensity can change how an electrical charge is transported could be powerful design idea," says Mele.

Future development of "photonic" and "spintronic" materials that transfer digitized information based on the spin of photons or electrons respectively is also made possible thanks to these results. Agarwal hopes to expand this work to include other optical beam patterns, such as "twisted light," which could be used to create new quantum computing materials that allow more information to be encoded onto a single photon of light.

"With quantum computing, all platforms are light-based, so it's the photon which is the carrier of quantum information. If we can configure our detectors on a chip, everything can be integrated, and we can read out the state of the photon directly," Agarwal says.

Agarwal and Mele emphasize the "heroic" effort made by Ji, including an additional year's measurements made while running an entirely new set of experiments that were crucial to the interpretation of the study. "I've rarely seen a graduate student faced with that challenge who was able not only to rise to it but to master it. She had the initiative to do something new, and she got it done," says Mele. [26]

Corkscrew photons may leave behind a spontaneous twist

Everything radiates. Whether it's a car door, a pair of shoes or the cover of a book, anything hotter than absolute zero (i.e., pretty much everything) is constantly shedding radiation in the form of photons, the quantum particles of light.

A twin process—absorption—is usually also present. As photons carry away energy, passers-by from the environment can be absorbed to replenish it. When absorption and emission occur at the same rate, scientists say that an object is in equilibrium with its environment. This often means that object and environment share the same temperature.

Far away from equilibrium, new behaviors can emerge. In a paper published August 1, 2019 as an Editors' Suggestion in the journal *Physical Review Letters*, scientists at JQI and Michigan State University suggest that certain materials may experience a spontaneous twisting force if they are hotter than their surroundings.

"The fact that a material might feel a torque due to a temperature difference with the environment is very unusual," says lead author Mohammad Maghrebi, a former JQI postdoctoral researcher who is now an assistant professor at Michigan State University.

The effect, which hasn't yet been observed in an experiment, is predicted to arise in a thin ribbon of a material called a topological insulator (TI)—something that allows electrical currentto flow on its surface but not through its innards.

In this case, the researchers made two additional assumptions about the TI. One is that it is hotter than its environment. And another is that the TI has some magnetic impurities that affect the behavior of electrons on its surface.

These magnetic impurities interact with a quantum property of the electrons called spin. Spin is part of the basic character of an electron, much like electric charge, and it describes the particle's intrinsic angular momentum—the tendency of an object to continue rotating. Photons, too, can carry angular momentum.

Although electrons don't physically rotate, they can still gain and lose angular momentum, albeit only in discrete chunks. Each electron has two spin values—up and down—and the magnetic impurities ensure that one value sits at a higher energy than the other. In the presence of these impurities, electrons can flip their spin from up to down and vice versa by emitting or absorbing a photon that carries the right amount of energy and angular momentum.

Maghrebi and two colleagues, JQI Fellows Jay Deep Sau and Alexey Gorshkov, showed that radiation emanating from this kind of TI carries angular momentum skewed in one rotational direction, like a corkscrew that twists clockwise. The material gets left with a deficit of angular momentum, causing it to feel a torque in the opposite direction (in this example, counterclockwise).

The authors say that TIs are ideal for spotting this effect because they play host to the right kind of interaction between electrons and light. TIs already link electron spin with the momentum of their motion, and it's through this motion that electrons in the material ordinarily absorb and emit light.

If an electron on the surface of this particular kind of TI starts with its spin pointing up, it can shed energy and angular momentum by changing its spin from up to down and emitting a photon. Since the TI is hotter than its environment, electrons will flip from up to down more often than the reverse. That's because the environment has a lower temperature and lacks the energy to replace the radiation coming from the TI. The result of this imbalance is a torque on the thin TI sample, driven by the random emission of radiation.

Future experiments might observe the effect in one of two ways, the authors say. The most likely method is indirect, requiring experimenters to heat up a TI by running a current through it and collecting the emitted light. By measuring the average angular momentum of the radiation, an experiment might detect the asymmetry and confirm one consequence of the new prediction.

A more direct—and likely more difficult—observation would involve actually measuring the torque on the thin film by looking for tiny rotations. Maghrebi says that he's brought up the idea to several experimentalists. "They were not horrified by having to measure something like a torque, but, at the same time, I think it really depends on the setup," he says. "It certainly didn't sound like it was impossible." [25]

Quantum microphone detects the presence of phonons

A superconducting qubit can be used to reliably detect the presence of multiple phonons at the same time, US physicists have demonstrated. Patricio Arrangoiz-Arriola and colleagues at Stanford University built their “quantum microphone” using materials that minimized phonon losses, while narrowing the spectra of their qubit’s emissions to reduce uncertainties. The technology could allow for new capabilities in quantum computing, including modems that link together many quantum computers at different locations.

While the quantum properties of photons have been explored and exploited extensively, those of quantized mechanical vibrations, known as phonons, have remained much more difficult to study. Although phonons are important for explaining many properties in solid materials, the technologies required to measure and control them have faced significant challenges because – in contrast to photons – the quantized states of phonons do not have well-defined energies. Instead, they exist as collective excitations at equally spaced energies.

The most successful attempts to detect phonons so far have involved a technique named quantum acoustics, in which an artificial atom is coupled to a vibrating nanostructure. This atom can be in one of two quantum states, depending on whether or not it has absorbed a phonon. In their study, Arrangoiz-Arriola's team devised a more sophisticated version of this setup – replacing the atom with a superconducting qubit to allow for stronger coupling with the nanostructure. Where the artificial atom would need to entirely absorb a phonon, this coupling allows the qubit to change states simply in the presence of one or more phonons.

To further improve their quantum microphone, Arrangoiz-Arriola and colleagues combined the qubit with a piezoelectric resonator, which produces a large voltage in response to mechanical deformation. This heightens the peaks of the energy spectra emitted by the qubit as it changed states. Shielding the hybrid qubit-resonator platform with a periodic crystal ensures that only the phonons produced by the nanostructure can interact with the qubit, while also minimizing losses of phonons to the surrounding environment.

The physicists then excited phonons through resonant vibrations of the nanostructures, and probed the peak positions of the qubit's resulting transition spectra – which shifted to different degrees depending on the number of phonons present. They observed energy shifts around five times larger than the linewidths of each peak, revealing the presence of up to three phonons with a high degree of certainty.

In future studies, Arrangoiz-Arriola's team hope to improve their setup to reveal phonon numbers without changing them, allowing for repeated measurements. Further developments could allow the quantum microphone to provide a basis for quantum modems, potentially creating networks of quantum computers in a variety of locations, and could also inform designs for novel architectures for quantum computers themselves.

The full results are reported in *Nature* [24]

Physicists developing quantum-enhanced sensors for real-life applications

A University of Oklahoma physicist, Alberto M. Marino, is developing quantum-enhanced sensors that could find their way into applications ranging from biomedical to chemical detection.

In a new study, Marino's team, in collaboration with the U.S. Department of Energy's Oak Ridge National Laboratory, demonstrates the ability of quantum states of light to enhance the sensitivities of state-of-the-art plasmonic sensors. The team presents the first implementation of a sensor with sensitivities considered state-of-the-art and shows how quantum-enhanced sensing can find its way into real-life applications.

"Quantum resources can enhance the sensitivity of a device beyond the classical shot noise limit and, as a result, revolutionize the field of metrology through the development of quantum enhanced sensors," said Marino, a professor in the Homer L. Dodge Department of Physics and Astronomy, OU College of Arts and Sciences. "In particular, plasmonic sensors offer a unique opportunity to enhance real-life devices."

Plasmonic sensors are currently used in a number of applications, such as biosensing, atmospheric monitoring, ultrasound diagnostics and chemical detection. These sensors can be probed with light and have been shown to operate at the shot noise limit. Thus, when interfaced with quantum states of light that exhibit reduced noise properties, the noise floor can be reduced below the classical shot noise limit. This makes it possible to obtain a quantum-based enhancement of the sensitivity.

A study on this project, "Quantum-Enhanced Plasmonic Sensing," has been published in the scientific journal *Optica*. [23]

A chip that allows for two-dimensional quantum walks

A team of researchers from Shanghai Jiao Tong University and the University of Science and Technology of China has developed a chip that allows for two-dimensional quantum walks of single photons on a physical device. In their paper published on the open access site, *Science Advances* the group describes the chip and why they believe developing it was important.

Quantum walks are the quantum version of classical random walks, which are a mathematical means for describing a natural random walk, e.g., simply wandering around randomly. To describe such walks, mathematicians and computer scientists use probability distribution grids that show a current position and possible next steps. Quantum walks are used to build models that depict randomly grown, sophisticated and complex networks such as the human neural network. They can also be used to create networks for actual use in applications, and might one day be used in quantum-based robots.

As the researchers note, a quantum computer should provide exponential advantages over classical systems due to their nature. To that end, scientists have been working to implement quantum walks in a physical machine as part of developing a truly useful quantum computer. In this new effort, the researchers report that they have developed a chip that carries out quantum walks on a two-dimensional 49x49 grid—the largest created so far by any team.

The three-dimensional chip, the team reports, was created using a technique called femtosecond writing. It uses the external geometry of photonic waveguide arrays as a means for carrying out the quantum walks using a single photon. They note also that they tested the chip by observing patterns and variance profiles and comparing them to simulation studies. They suggest further that in addition to making progress toward a truly useful quantum computer, the chip could also be used to boost the performance of analog quantum computing or quantum simulators.

If researchers can create quantum computers with very large, or even unlimited size grids, it might be possible to create and use networks as complex as the human nervous system. [22]

New quantum probability rule offers novel perspective of wave function collapse

Quantum theory is based heavily on probabilities, since measuring a quantum system doesn't produce the same outcome every time, but instead yields one of many outcomes that each occur with a certain probability. Now in a new paper, physicists have presented a new quantum probability rule for assigning probabilities to measurement outcomes, or events, that essentially combines two of the most important quantum probability rules (the Born rule and the wave function collapse rule) into one.

The physicists, Sally Shrapnel, Fabio Costa, and Gerard Milburn, at The University of Queensland in Australia, have published a paper on the new quantum probability rule in the *New Journal of Physics*.

One of the most important probability rules in quantum theory is the Born rule, which gives the probability that a measurement yields a certain event. However, things get a little bit more complicated when predicting consecutive events. Although in classical scenarios it's possible to assign joint probabilities to consecutive events using conditioning, in quantum scenarios this is not possible since each measurement necessarily disturbs the system. So in quantum mechanics, the state must be updated with this new information after every measurement.

In order to update the state, a "state update rule" or "collapse rule" is applied. In the new paper, the physicists explain that this update is basically an "ad hoc ingredient," since it is introduced as an axiom (which cannot be proved), and is a completely separate entity from the Born rule. Although this additional rule works well for practical purposes, it poses problems for understanding the true nature of quantum theory—in particular, for interpretations of quantum theory as a statement about the knowledge of reality, rather than of reality itself.

To address these problems, the physicists propose and prove a unified probability rule, which they call the "Quantum Process Rule." They show that this rule is more fundamental than the Born rule, as both the Born rule and the state update, or collapse, rule can be derived from this new rule—that is, the update rule does not need to be independently introduced. Unlike the Born rule, the Quantum Process Rule can assign joint probabilities to consecutive events.

One of the interesting implications of showing that wave function collapse follows from the new probability rule is that it suggests that the collapse does not need to be regarded as a fundamental aspect of quantum theory. This implication offers an alternative perspective of wave function collapse, as well as a new understanding of the nature of quantum theory.

"The main significance of the work is that we derive a single, unified probability rule that subsumes both the Born rule and the collapse rule," Shrapnel told Phys.org. "This means that one no longer needs to explain wave function collapse in terms of a physical process, but can instead view this part of the formalism as simply a case of classical probabilistic conditioning. It is this latter possibility that means we can consider the quantum state as being about our knowledge rather than a direct description of physical reality." [21]

Probabilistic computing takes artificial intelligence to the next step

The potential impact of Artificial Intelligence (AI) has never been greater—but we'll only be successful if AI can deliver smarter and more intuitive answers.

A key barrier to AI today is that natural data fed to a computer is largely unstructured and "noisy."

It's easy for humans to sort through natural data. For example: If you are driving a car on a residential street and see a ball roll in front of you, you would stop, assuming there is a small child not far behind that ball. Computers today don't do this. They are built to assist humans with precise productivity tasks. Making computers efficient at dealing with probabilities at scale is central to our ability to transform current systems and applications from advanced computational aids into intelligent partners for understanding and decision-making.

This is why probabilistic computing is one key component to AI and central to addressing these challenges. Probabilistic computing will allow future systems to comprehend and compute with uncertainties inherent in natural data, which will enable us to build computers capable of understanding, predicting and decision-making.

Today at Intel, we are observing an unprecedented growth of applications that rely on analysis of noisy natural data – different and even conflicting information. Such applications aim to assist humans with a higher level of intelligence and awareness about the environments in which they operate. Cutting through this noisy minefield is central to our ability to transform computers into intelligent partners that can understand and act on information with human-like fidelity.

Research into probabilistic computing is not a new area of study, but the improvements in high-performance computing and deep learning algorithms may lead probabilistic computing into a new era. In the next few years, we expect that research in probabilistic computing will lead to significant improvements in the reliability, security, serviceability and performance of AI systems, including hardware designed specifically for probabilistic computing. These advancements are critical to deploying applications into the real world – from smart homes to smart cities.

To accelerate our work in probabilistic computing, Intel is increasing its research investment in probabilistic computing and we are working with partners to pursue this goal.

Establishing the Intel Strategic Research Alliance for Probabilistic Computing

Realizing the full potential of probabilistic computing involves holistic integration of multiple levels in computing technology. Today, Intel underscored its commitment to integrated and collaborative implementation of emerging computing architectures and a sound ecosystem enablement strategy by issuing a call to the academic and start-up communities to partner with us to advance probabilistic computing from the lab to reality across these vectors: benchmark applications, adversarial attack mitigations, probabilistic frameworks and software and hardware optimization.

An Eye on What's Next

We are incredibly eager to see the proposals to advance probabilistic computing and to continue this research with the potential to raise the bar for what AI can help us achieve. Academic proposals are expected to be submitted by May 25th and among them we will select the best research teams.

We began this journey with research into neuromorphic computing – focusing on our understanding of the human brain and its associated computational processes. The start of the neuromorphic research community announced on March 1 is also on track and we are planning to continue to scale up our Loihi on the cloud to allow researchers access to cutting-edge hardware. We see a path to reach 100 billion synapses on a single system in 2019.

Furthermore, Intel has already been working to decode the brain and advance the next stage in neuroscience as part of our research partnership with Princeton University. We are looking forward to further understanding the flow of intelligence and decision-making through our probabilistic computing work. [20]

Deep learning comes full circle

For years, the people developing artificial intelligence drew inspiration from what was known about the human brain, and it has enjoyed a lot of success as a result. Now, AI is starting to return the favor.

Although not explicitly designed to do so, certain artificial intelligence systems seem to mimic our brains' inner workings more closely than previously thought, suggesting that both AI and our minds have converged on the same approach to solving problems. If so, simply watching AI at work could help researchers unlock some of the deepest mysteries of the brain.

"There's a real connection there," said Daniel Yamins, assistant professor of psychology. Now, Yamins, who is also a faculty scholar of the Stanford Neurosciences Institute and a member of Stanford Bio-X, and his lab are building on that connection to produce better theories of the brain – how it perceives the world, how it shifts efficiently from one task to the next and perhaps, one day, how it thinks.

A vision problem for AI

Artificial intelligence has been borrowing from the brain since its early days, when computer scientists and psychologists developed algorithms called neural networks that loosely mimicked the brain. Those algorithms were frequently criticized for being biologically implausible – the "neurons" in neural networks were, after all, gross simplifications of the real neurons that make up the brain. But computer scientists didn't care about biological plausibility. They just wanted systems that worked, so they extended neural network models in whatever way made the algorithm best able to carry out certain tasks, culminating in what is now called deep learning.

Then came a surprise. In 2012, AI researchers showed that a deep learning neural network could learn to identify objects in pictures as well as a human being, which got neuroscientists wondering: How did deep learning do it?

The same way the brain does, as it turns out. In 2014, Yamins and colleagues showed that a deep learning system that had learned to identify objects in pictures – nearly as well as humans could – did so in a way that closely mimicked the way the brain processes vision. In fact, the computations the deep learning system performed matched activity in the brain's vision-processing circuits substantially better than any other model of those circuits.

Around the same time, other teams made similar observations about parts of the brain's vision– and movement-processing circuits, suggesting that given the same kind of problem, deep learning and the brain had evolved similar ways of coming up with a solution. More recently, Yamins and colleagues have demonstrated similar observations in the brain's auditory system.

On one hand, that's not a big surprise. Although the technical details differ, deep learning's conceptual organization is borrowed directly from what neuroscientists already knew about the organization of neurons in the brain.

But the success of Yamins and colleagues' approach and others like it depends equally as much on another, more subtle choice. Rather than try to get the deep learning system to directly match what the brain does at the level of individual neurons, as many researchers had done, Yamins and colleagues simply gave their deep learning system the same problem: Identify objects in pictures. Only after it had solved that problem did the researchers compare how deep learning and the brain arrived at their solutions – and only then did it become clear that their methods were essentially the same.

"The correspondence between the models and the visual system is not entirely a coincidence, because one directly inspired the other," said Daniel Bear, a postdoctoral researcher in Yamins' group, "but it's still remarkable that it's as good a correspondence as it is."

One likely reason for that, Bear said, is natural selection and evolution. "Basically, object recognition was a very evolutionarily important task" for animals to solve – and solve well, if they wanted to tell the difference between something they could eat and something that could eat them. Perhaps trying to do that as well as humans and other animals do – except with a computer – led researchers to find essentially the same solution.

Seek what the brain seeks

Whatever the underlying reason, insights gleaned from the 2014 study led to what Yamins calls goal-directed models of the brain: Rather than try to model neural activity in the brain directly, instead train artificial intelligence to solve problems the brain needs to solve, then use the resulting AI system as a model of the brain. Since 2014, Yamins and collaborators have been refining the original goal-directed model of the brain's vision circuits and extending the work in new directions, including understanding the neural circuits that process inputs from rodents' whiskers.

In perhaps the most ambitious project, Yamins and postdoctoral fellow Nick Haber are investigating how infants learn about the world around them through play. Their infants – actually relatively simple computer simulations – are motivated only by curiosity. They explore their worlds by moving around and interacting with objects, learning as they go to predict what happens when they hit balls or simply turn their heads. At the same time, the model learns to predict what parts of the world it doesn't understand, then tries to figure those out.

While the computer simulation begins life – so to speak – knowing essentially nothing about the world, it eventually figures out how to categorize different objects and even how to smash two or three of them together. Although direct comparisons with babies' neural activity might be premature, the model could help researchers better understand how infants use play to learn about their environments, Haber said.

On the other end of the spectrum, models inspired by artificial intelligence could help solve a puzzle about the physical layout of the brain, said Eshed Margalit, a graduate student in neurosciences. As the vision circuits in infants' brains develop, they form specific patches – physical clusters of neurons – that respond to different kinds of objects. For example, humans and other primates all form a face patch that is active almost exclusively when they look at faces.

Exactly why the brain forms those patches, Margalit said, isn't clear. The brain doesn't need a face patch to recognize faces, for example. But by building on AI models like Yamins' that already solve object recognition tasks, "we can now try to model that spatial structure and ask questions about why the brain is laid out this way and what advantages it might give an organism," Margalit said.

Closing the loop

There are other issues to tackle as well, notably how artificial intelligence systems learn. Right now, AI needs much more training – and much more explicit training – than humans do in order to perform as well on tasks like object recognition, although how humans succeed with so little data remains unclear.

A second issue is how to go beyond models of vision and other sensory systems. "Once you have a sensory impression of the world, you want to make decisions based on it," Yamins said. "We're trying to make models of decision making, learning to make decisions and how you interface between sensory systems, decision making and memory." Yamins is starting to address those ideas with Kevin Feigelis, a graduate student in physics, who is building AI models that can learn to solve many different kinds of problems and switch between tasks as needed, something very few AI systems are able to do.

In the long run, Yamins and the other members of his group said all of those advances could feed into more capable artificial intelligence systems, just as earlier neuroscience research helped foster the development of deep learning. "I think people in artificial intelligence are realizing there are certain very good next goals for cognitively inspired artificial intelligence," Haber said, including systems like his that learn by actively exploring their worlds. "People are playing with these ideas." [19]

Scientists pioneer use of deep learning for real-time gravitational wave discovery

Scientists at the National Center for Supercomputing Applications (NCSA), located at the University of Illinois at Urbana-Champaign, have pioneered the use of GPU-accelerated deep learning for rapid detection and characterization of gravitational waves. This new approach will enable astronomers to study gravitational waves using minimal computational resources, reducing time to discovery and increasing the scientific reach of gravitational wave astrophysics. This innovative research was recently published in *Physics Letters B*.

Combining deep learning algorithms, numerical relativity simulations of black hole mergers—obtained with the Einstein Toolkit run on the Blue Waters supercomputer—and data from the LIGO Open Science Center, NCSA Gravity Group researchers Daniel George and Eliu Huerta produced Deep Filtering, an end-to-end time-series signal processing method. Deep Filtering achieves similar sensitivities and lower errors compared to established gravitational wave detection algorithms, while being far more computationally efficient and more resilient to noise anomalies. The method allows faster than real-time processing of gravitational waves in LIGO's raw data, and also enables new physics, since it can detect new classes of gravitational wave sources that may go unnoticed with existing detection algorithms. George and Huerta are extending this method to identify in real-time electromagnetic counterparts to gravitational wave events in future LSST data.

NCSA's Gravity Group leveraged NCSA resources from its Innovative Systems Laboratory, NCSA's Blue Waters supercomputer, and collaborated with talented interdisciplinary staff at the University of Illinois. Also critical to this research were the GPUs (Tesla P100 and DGX-1) provided by NVIDIA, which enabled an accelerated training of neural networks. Wolfram Research also played an important role, as the Wolfram Language was used in creating this framework for deep learning.

George and Huerta worked with NVIDIA and Wolfram researchers to create this demo to visualize the architecture of Deep Filtering, and to get insights into its neuronal activity during the detection and characterization of real gravitational wave events. This demo highlights all the components of Deep Filtering, exhibiting its detection sensitivity and computational performance. [18]

Mathematicians develop model for how new ideas emerge

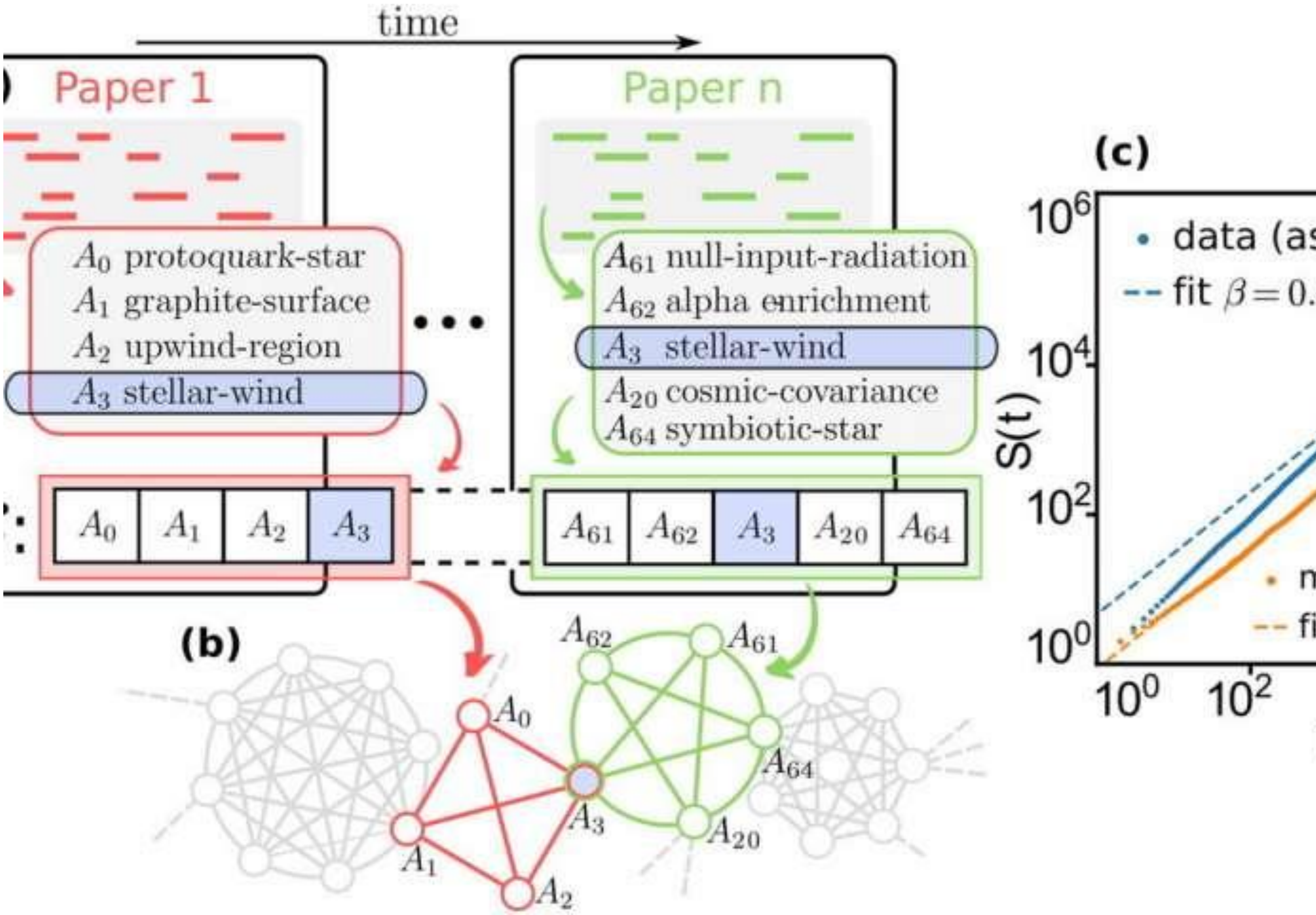
Researchers from Queen Mary University of London have developed a mathematical model for the emergence of innovations.

Studying creative processes and understanding how innovations arise and how novelties can trigger further discoveries could lead to effective interventions to nurture the success and sustainable growth of society.

Empirical findings have shown that the way in which novelties are discovered follows similar patterns in a variety of different contexts including science, arts, and technology.

The study, published in *Physical Review Letters*, introduces a new mathematical framework that correctly reproduces the rate at which novelties emerge in real systems, known as Heaps' law, and can explain why discoveries are strongly correlated and often come in clusters.

It does this by translating the theory of the 'adjacent possible', initially formulated by Stuart Kauffman in the context of biological systems, into the language of complex networks. The adjacent possible is the set of all novel opportunities that open up when a new discovery is made. Networks have emerged as a powerful way to both investigate real world systems, by capturing the essential relations between the components, and to model the hidden structure behind many complex social phenomena.



Growth of knowledge in science. (a) An empirical sequence of scientific concepts S is extracted from a temporally ordered sequence of papers by concatenating, for each scientific field, the relevant concepts present in the abstracts. (b) …more

In this work, networks are used to model the underlying space of relations among concepts.

Lead author Professor Vito Latora, from Queen Mary's School of Mathematical Sciences, said: "This research opens up new directions for the modelling of innovation, together with a new framework that could become important in the investigation of technological, biological, artistic, and commercial systems."

He added: "Studying the processes through which innovations arise can help understanding the main ingredients behind a winning idea, a breakthrough technology or a successful commercial activity, and is fundamental to devise effective data-informed decisions, strategies, and interventions to nurture the success and sustainable growth of our society."

In the study, the discovery process is modelled as a particular class of random walks, named 'reinforced' walks, on an underlying network of relations among concepts and ideas. An innovation corresponds to the first visit of a site of the network, and every time a walker moves from a concept to another, such association (an edge in the network) is reinforced so that it will be used more frequently in the future. The researchers named this the 'edge-reinforced random walk' model.

To show how the model works in a real case, they also constructed a dataset of 20 years of scientific publications in different disciplines, such as astronomy, ecology, economics and mathematics to analyse the appearance of new concepts. This showed that, despite its simplicity, the edge-reinforced random walk model is able to reproduce how knowledge grows in modern science.

Professor Vito Latora added: "The framework we present constitutes a new approach for the study of discovery processes, in particular those for which the underlying network can be directly reconstructed from empirical data, for example users listening to music over a similarity network between songs. We are already working on this idea, together with an extended version of our model, where we study the collective exploration of these networked spaces by considering multiple walkers at the same time." [17]

Rise of the quantum thinking machines

Quantum computers can be made to utilize effects such as quantum coherence and entanglement to accelerate machine learning.

Although we typically view information as being an abstract or virtual entity, information, of course, must be stored in a physical medium. Information processing devices such as computers and phones are therefore fundamentally governed by the laws of physics. In this way, the fundamental physical limits of an agent's ability to learn are governed by the laws of physics. The best known theory of physics is quantum theory, which ultimately must be used to determine the absolute physical limits of a machine's ability to learn.

A quantum algorithm is a stepwise procedure performed on a quantum computer to solve a problem such as searching a database. Quantum machine learning software makes use of quantum algorithms to process information in ways that classical computers cannot. These quantum effects open up exciting new avenues which can, in principle, outperform the best known classical algorithms when solving certain machine learning problems. This is known as quantum enhanced machine learning.

Machine learning methods use mathematical algorithms to search for certain patterns in large data sets. Machine learning is widely used in biotechnology, pharmaceuticals, particle physics and many other fields. Thanks to the ability to adapt to new data, machine learning greatly exceeds the ability of people. Despite this, machine learning cannot cope with certain difficult tasks.

Quantum enhancement is predicted to be possible for a host of machine learning tasks, ranging from optimization to quantum enhanced deep learning.

In the new paper published in Nature, a group of scientists led by Skoltech Associate Professor Jacob Biamonte produced a feasibility analysis outlining what steps can be taken for practical quantum enhanced machine learning.

The prospects of using quantum computers to accelerate machine learning has generated recent excitement due to the increasing capabilities of quantum computers. This includes a commercially available 2000 spin quantum accelerated annealing by the Canada-based company D-Wave Systems Inc. and a 16 qubit universal quantum processor by IBM which is accessible via a (currently free) cloud service.

The availability of these devices has led to increased interest from the machine learning community. The interest comes as a bit of a shock to the traditional quantum physics community, in which researchers have thought that the primary applications of quantum computers would be using quantum computers to simulate chemical physics, which can be used in the pharmaceutical industry for drug discovery. However, certain quantum systems can be mapped to certain machine learning models, particularly deep learning models. Quantum machine learning can be used to work in tandem with these existing methods for quantum chemical emulation, leading to even greater capabilities for a new era of quantum technology.

"Early on, the team burned the midnight oil over Skype, debating what the field even was—our synthesis will hopefully solidify topical importance. We submitted our draft to Nature, going forward subject to significant changes. All in all, we ended up writing three versions over eight months with nothing more than the title in common," said lead study author Biamonte. [16]

A Machine Learning Systems That Called Neural Networks Perform Tasks by Analyzing Huge Volumes of Data

Neural networks learn how to carry out certain tasks by analyzing large amounts of data displayed to them. These machine learning systems continually learn and readjust to be able to carry out the task set out before them. Understanding how neural networks work helps researchers to develop better applications and uses for them.

At the 2017 Conference on Empirical Methods on Natural Language Processing earlier this month, MIT researchers demonstrated a new general-purpose technique for making sense of neural networks that are able to carry out natural language processing tasks where they attempt to extract data written in normal text opposed to something of a structured language like database-query language.

The new technique works great in any system that reads the text as input and produces symbols as the output. One such example of this can be seen in an automatic translator. It works without the need to access any underlying software too. Tommi Jaakkola is Professor of Electrical Engineering and Computer Science at MIT and one of the authors on the paper. He says, “I can’t just do a simple randomization. And what you are predicting is now a more complex object, like a sentence, so what does it mean to give an explanation?”

As part of the research, Jaakkola, and colleague David Alvarez-Melis, an MIT graduate student in electrical engineering and computer science and first author on the paper, used a black-box neural net in which to generate test sentences to feed black-box neural nets. The duo began by teaching the network to compress and decompress natural sentences. As the training continues the encoder and decoder get evaluated simultaneously depending on how closely the decoder's output matches up with the encoder's input.

Neural nets work on probabilities. For example, an object-recognition system could be fed an image of a cat, and it would process that image as it saying 75 percent probability of being a cat, while still having a 25 percent probability that it's a dog. Along with that same line, Jaakkola and Alvarez-Melis' sentence compressing network has alternative words for each of those in a decoded sentence along with the probability that each is correct. So, once the system has generated a list of closely related sentences they're then fed to a black-box natural language processor. This then allows the researchers to analyze and determine which inputs have an effect on which outputs.

During the research, the pair applied this technique to three different types of a natural language processing system. The first one inferred the way in which words were pronounced; the second was a set of translators, and the third was a simple computer dialogue system which tried to provide adequate responses to questions or remarks. In looking at the results, it was clear and pretty obvious that the translation systems had strong dependencies on individual words of both the input and output sentences. A little more surprising, however, was the identification of gender biases in the texts on which the machine translation systems were trained. The dialogue system was too small to take advantage of the training set.

"The other experiment we do is in flawed systems," says Alvarez-Melis. "If you have a black-box model that is not doing a good job, can you first use this kind of approach to identify problems? A motivating application of this kind of interpretability is to fix systems, to improve systems, by understanding what they're getting wrong and why." [15]

Active machine learning for the discovery and crystallization of gigantic polyoxometalate molecules

Who is the better experimentalist, a human or a robot? When it comes to exploring synthetic and crystallization conditions for inorganic gigantic molecules, actively learning machines are clearly ahead, as demonstrated by British Scientists in an experiment with polyoxometalates published in the journal Angewandte Chemie.

Polyoxometalates form through self-assembly of a large number of metal atoms bridged by oxygen atoms. Potential uses include catalysis, electronics, and medicine. Insights into the self-organization processes could also be of use in developing functional chemical systems like "molecular machines".

Polyoxometalates offer a nearly unlimited variety of structures. However, it is not easy to find new ones, because the aggregation of complex inorganic molecules to gigantic molecules is a process that is difficult to predict. It is necessary to find conditions under which the building blocks aggregate and then also crystallize, so that they can be characterized.

A team led by Leroy Cronin at the University of Glasgow (UK) has now developed a new approach to define the range of suitable conditions for the synthesis and crystallization of polyoxometalates.

It is based on recent advances in machine learning, known as active learning. They allowed their trained machine to compete against the intuition of experienced experimenters. The test example was Na(6)[Mo(120)Ce(6)O(366)H(12)(H(2)O)(78)]·200 H(2)O, a new, ring-shaped polyoxometalate cluster that was recently discovered by the researchers' automated chemical robot.

In the experiment, the relative quantities of the three necessary reagent solutions were to be varied while the protocol was otherwise prescribed. The starting point was a set of data from successful and unsuccessful crystallization experiments. The aim was to plan ten experiments and then use the results from these to proceed to the next set of ten experiments - a total of one hundred crystallization attempts.

Although the flesh-and-blood experimenters were able to produce more successful crystallizations, the far more "adventurous" machine algorithm was superior on balance because it covered a significantly broader domain of the "crystallization space". The quality of the prediction of whether an experiment would lead to crystallization was improved significantly more by the machine than the human experimenters. A series of 100 purely random experiments resulted in no improvement. In addition, the machine discovered a range of conditions that led to crystals which would not have been expected based on pure intuition. This "unbiased" automated method makes the discovery of novel compounds more probably than reliance on human intuition. The researchers are now looking for ways to make especially efficient "teams" of man and machine. [14]

Using machine learning to understand materials

Whether you realize it or not, machine learning is making your online experience more efficient. The technology, designed by computer scientists, is used to better understand, analyze, and categorize data. When you tag your friend on Facebook, clear your spam filter, or click on a suggested YouTube video, you're benefitting from machine learning algorithms.

Machine learning algorithms are designed to improve as they encounter more data, making them a versatile technology for understanding large sets of photos such as those accessible from Google Images. Elizabeth Holm, professor of materials science and engineering at Carnegie Mellon University, is leveraging this technology to better understand the enormous number of research images accumulated in the field of materials science. This unique application is an interdisciplinary approach to machine learning that hasn't been explored before.

"Just like you might search for cute cat pictures on the internet, or Facebook recognizes the faces of your friends, we are creating a system that allows a computer to automatically understand the visual data of materials science," explains Holm.

The field of materials science usually relies on human experts to identify research images by hand. Using machine learning algorithms, Holm and her group have created a system that automatically recognizes and categorizes microstructural images of materials. Her goal is to make it more efficient for materials scientists to search, sort, classify, and identify important information in their visual data.

"In materials science, one of our fundamental data is pictures," explains Holm. "Images contain information that we recognize, even when we find it difficult to quantify numerically."

Holm's machine learning system has several different applications within the materials science field including research, industry, publishing, and academia. For example, the system could be used to create a visual search of a scientific journal archives so that a researcher could find out whether a similar image had ever been published. Similarly, the system can be used to automatically search and categorize image archives in industries or research labs. "Big companies can have archives of 600,000 or more research images. No one wants to look through those, but they want to use that data to better understand their products," explains Holm. "This system has the power to unlock those archives."

Holm and her group have been working on this research for about three years and are continuing to grow the project, especially as it relates to the metal 3-D printing field. For example, they are beginning to compile a database of experimental and simulated metal powder micrographs in order to better understand what types of raw materials are best suited for 3-D printing processes.

Holm published an article about this research in the December 2015 issue of Computational Materials Science titled "A computer vision approach for automated analysis and classification of microstructural image data." [13]

Artificial intelligence helps in the discovery of new materials

With the help of artificial intelligence, chemists from the University of Basel in Switzerland have computed the characteristics of about two million crystals made up of four chemical elements. The researchers were able to identify 90 previously unknown thermodynamically stable crystals that can be regarded as new materials.

They report on their findings in the scientific journal Physical Review Letters.

Elpasolite is a glassy, transparent, shiny and soft mineral with a cubic crystal structure. First discovered in El Paso County (Colorado, USA), it can also be found in the Rocky Mountains, Virginia and the Apennines (Italy). In experimental databases, elpasolite is one of the most frequently found quaternary crystals (crystals made up of four chemical elements). Depending on its composition, it can be a metallic conductor, a semi-conductor or an insulator, and may also emit light when exposed to radiation.

These characteristics make elpasolite an interesting candidate for use in scintillators (certain aspects of which can already be demonstrated) and other applications. Its chemical complexity means that, mathematically speaking, it is practically impossible to use quantum mechanics to predict every theoretically viable combination of the four elements in the structure of elpasolite.

Machine learning aids statistical analysis

Thanks to modern artificial intelligence, Felix Faber, a doctoral student in Prof. Anatole von Lilienfeld's group at the University of Basel's Department of Chemistry, has now succeeded in solving this material design problem. First, using quantum mechanics, he generated predictions for thousands of elpasolite crystals with randomly determined chemical compositions. He then used the results to train statistical machine learning models (ML models). The improved algorithmic strategy achieved a predictive accuracy equivalent to that of standard quantum mechanical approaches.

ML models have the advantage of being several orders of magnitude quicker than corresponding quantum mechanical calculations. Within a day, the ML model was able to predict the formation energy – an indicator of chemical stability – of all two million elpasolite crystals that theoretically can be obtained from the main group elements of the periodic table. In contrast, performance of the calculations by quantum mechanical means would have taken a supercomputer more than 20 million hours.

Unknown materials with interesting characteristics

An analysis of the characteristics computed by the model offers new insights into this class of materials. The researchers were able to detect basic trends in formation energy and identify 90 previously unknown crystals that should be thermodynamically stable, according to quantum mechanical predictions.

On the basis of these potential characteristics, elpasolite has been entered into the Materials Project material database, which plays a key role in the Materials Genome Initiative. The initiative was launched by the US government in 2011 with the aim of using computational support to accelerate the discovery and the experimental synthesis of interesting new materials.

Some of the newly discovered elpasolite crystals display exotic electronic characteristics and unusual compositions. "The combination of artificial intelligence, big data, quantum mechanics and supercomputing opens up promising new avenues for deepening our understanding of materials and discovering new ones that we would not consider if we relied solely on human intuition," says study director von Lilienfeld. [12]

Physicists are putting themselves out of a job, using artificial intelligence to run a complex experiment

The experiment, developed by physicists from The Australian National University (ANU) and UNSW ADFA, created an extremely cold gas trapped in a laser beam, known as a Bose-Einstein condensate, replicating the experiment that won the 2001 Nobel Prize.

"I didn't expect the machine could learn to do the experiment itself, from scratch, in under an hour," said co-lead researcher Paul Wigley from the ANU Research School of Physics and Engineering.

"A simple computer program would have taken longer than the age of the Universe to run through all the combinations and work this out."

Bose-Einstein condensates are some of the coldest places in the Universe, far colder than outer space, typically less than a billionth of a degree above absolute zero.

They could be used for mineral exploration or navigation systems as they are extremely sensitive to external disturbances, which allows them to make very precise measurements such as tiny changes in the Earth's magnetic field or gravity.

The artificial intelligence system's ability to set itself up quickly every morning and compensate for any overnight fluctuations would make this fragile technology much more useful for field measurements, said co-lead researcher Dr Michael Hush from UNSW ADFA.

"You could make a working device to measure gravity that you could take in the back of a car, and the artificial intelligence would recalibrate and fix itself no matter what," he said.

"It's cheaper than taking a physicist everywhere with you."

The team cooled the gas to around 1 microkelvin, and then handed control of the three laser beams over to the artificial intelligence to cool the trapped gas down to nanokelvin.

Researchers were surprised by the methods the system came up with to ramp down the power of the lasers.

"It did things a person wouldn't guess, such as changing one laser's power up and down, and compensating with another," said Mr Wigley.

"It may be able to come up with complicated ways humans haven't thought of to get experiments colder and make measurements more precise.

The new technique will lead to bigger and better experiments, said Dr Hush.

"Next we plan to employ the artificial intelligence to build an even larger Bose-Einstein condensate faster than we've seen ever before," he said.

The research is published in the Nature group journal Scientific Reports. [11]

Quantum experiments designed by machines

The idea was developed when the physicists wanted to create new quantum states in the laboratory, but were unable to conceive of methods to do so. "After many unsuccessful attempts to come up with an experimental implementation, we came to the conclusion that our intuition about these phenomena seems to be wrong. We realized that in the end we were just trying random arrangements of quantum building blocks. And that is what a computer can do as well - but thousands of times faster", explains Mario Krenn, PhD student in Anton Zeilinger's group and first author research.

After a few hours of calculation, their algorithm - which they call Melvin - found the recipe to the question they were unable to solve, and its structure surprised them. Zeilinger says: "Suppose I want build an experiment realizing a specific quantum state I am interested in. Then humans intuitively consider setups reflecting the symmetries of the state. Yet Melvin found out that the most simple realization can be asymmetric and therefore counterintuitive. A human would probably never come up with that solution."

The physicists applied the idea to several other questions and got dozens of new and surprising answers. "The solutions are difficult to understand, but we were able to extract some new experimental tricks we have not thought of before. Some of these computer-designed experiments are being built at the moment in our laboratories", says Krenn.

Melvin not only tries random arrangements of experimental components, but also learns from previous successful attempts, which significantly speeds up the discovery rate for more complex solutions. In the future, the authors want to apply their algorithm to even more general questions in quantum physics, and hope it helps to investigate new phenomena in laboratories. [10]

Moving electrons around loops with light: A quantum device based on geometry

Researchers at the University of Chicago's Institute for Molecular Engineering and the University of Konstanz have demonstrated the ability to generate a quantum logic operation, or rotation of the qubit, that - surprisingly—is intrinsically resilient to noise as well as to variations in the strength or duration of the control. Their achievement is based on a geometric concept known as the Berry phase and is implemented through entirely optical means within a single electronic spin in diamond.

Their findings were published online Feb. 15, 2016, in Nature Photonics and will appear in the March print issue. "We tend to view quantum operations as very fragile and susceptible to noise, especially when compared to conventional electronics," remarked David Awschalom, the Liew Family Professor of Molecular Engineering and senior scientist at Argonne National Laboratory, who led the research. "In contrast, our approach shows incredible resilience to external influences and fulfills a key requirement for any practical quantum technology."

Quantum geometry

When a quantum mechanical object, such as an electron, is cycled along some loop, it retains a memory of the path that it travelled, the Berry phase. To better understand this concept, the Foucault pendulum, a common staple of science museums helps to give some intuition. A pendulum, like those in a grandfather clock, typically oscillates back and forth within a fixed plane. However, a Foucault pendulum oscillates along a plane that gradually rotates over the course of a day due to Earth's rotation, and in turn knocks over a series of pins encircling the pendulum.

The number of knocked-over pins is a direct measure of the total angular shift of the pendulum's oscillation plane, its acquired geometric phase. Essentially, this shift is directly related to the location of the pendulum on Earth's surface as the rotation of Earth transports the pendulum along a specific closed path, its circle of latitude. While this angular shift depends on the particular path traveled, Awschalom said, it remarkably does not depend on the rotational speed of Earth or the oscillation frequency of the pendulum.

"Likewise, the Berry phase is a similar path-dependent rotation of the internal state of a quantum system, and it shows promise in quantum information processing as a robust means to manipulate qubit states," he said.

A light touch

In this experiment, the researchers manipulated the Berry phase of a quantum state within a nitrogen-vacancy (NV) center, an atomic-scale defect in diamond. Over the past decade and a half, its electronic spin state has garnered great interest as a potential qubit. In their experiments, the team members developed a method with which to draw paths for this defect's spin by varying the applied laser light. To demonstrate Berry phase, they traced loops similar to that of a tangerine slice within the quantum space of all of the potential combinations of spin states.

"Essentially, the area of the tangerine slice's peel that we drew dictated the amount of Berry phase that we were able to accumulate," said Christopher Yale, a postdoctoral scholar in Awschalom's laboratory, and one of the co-lead authors of the project.

This approach using laser light to fully control the path of the electronic spin is in contrast to more common techniques that control the NV center spin, through the application of microwave fields. Such an approach may one day be useful in developing photonic networks of these defects, linked and controlled entirely by light, as a way to both process and transmit quantum information.

A noisy path

A key feature of Berry phase that makes it a robust quantum logic operation is its resilience to noise sources. To test the robustness of their Berry phase operations, the researchers intentionally added noise to the laser light controlling the path. As a result, the spin state would travel along its intended path in an erratic fashion.

However, as long as the total area of the path remained the same, so did the Berry phase that they measured.

"In particular, we found the Berry phase to be insensitive to fluctuations in the intensity of the laser. Noise like this is normally a bane for quantum control," said Brian Zhou, a postdoctoral scholar in the group, and co-lead author.

"Imagine you're hiking along the shore of a lake, and even though you continually leave the path to go take pictures, you eventually finish hiking around the lake," said F. Joseph Heremans, co-lead author, and now a staff scientist at Argonne National Laboratory. "You've still hiked the entire loop regardless of the bizarre path you took, and so the area enclosed remains virtually the same."

These optically controlled Berry phases within diamond suggest a route toward robust and faulttolerant quantum information processing, noted Guido Burkard, professor of physics at the University of Konstanz and theory collaborator on the project.

"Though its technological applications are still nascent, Berry phases have a rich underlying mathematical framework that makes them a fascinating area of study," Burkard said. [9]

Researchers demonstrate 'quantum surrealism'

In a new version of an old experiment, CIFAR Senior Fellow Aephraim Steinberg (University of Toronto) and colleagues tracked the trajectories of photons as the particles traced a path through one of two slits and onto a screen. But the researchers went further, and observed the "nonlocal" influence of another photon that the first photon had been entangled with.

The results counter a long-standing criticism of an interpretation of quantum mechanics called the De Broglie-Bohm theory. Detractors of this interpretation had faulted it for failing to explain the behaviour of entangled photons realistically. For Steinberg, the results are important because they give us a way of visualizing quantum mechanics that's just as valid as the standard interpretation, and perhaps more intuitive.

"I'm less interested in focusing on the philosophical question of what's 'really' out there. I think the fruitful question is more down to earth. Rather than thinking about different metaphysical interpretations, I would phrase it in terms of having different pictures. Different pictures can be useful. They can help shape better intuitions."

At stake is what is "really" happening at the quantum level. The uncertainty principle tells us that we can never know both a particle's position and momentum with complete certainty. And when we do interact with a quantum system, for instance by measuring it, we disturb the system. So if we fire a photon at a screen and want to know where it will hit, we'll never know for sure exactly where it will hit or what path it will take to get there.

The standard interpretation of quantum mechanics holds that this uncertainty means that there is no "real" trajectory between the light source and the screen. The best we can do is to calculate a "wave function" that shows the odds of the photon being in any one place at any time, but won't tell us where it is until we make a measurement.

Yet another interpretation, called the De Broglie-Bohm theory, says that the photons do have real trajectories that are guided by a "pilot wave" that accompanies the particle. The wave is still probabilistic, but the particle takes a real trajectory from source to target. It doesn't simply "collapse" into a particular location once it's measured.

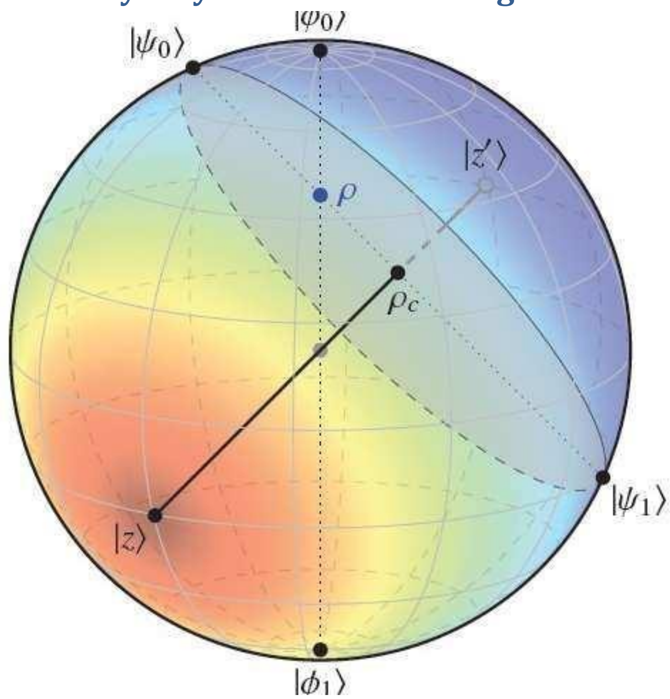
In 2011 Steinberg and his colleagues showed that they could follow trajectories for photons by subjecting many identical particles to measurements so weak that the particles were barely disturbed, and then averaging out the information. This method showed trajectories that looked similar to classical ones - say, those of balls flying through the air.

But critics had pointed out a problem with this viewpoint. Quantum mechanics also tells us that two particles can be entangled, so that a measurement of one particle affects the other. The critics complained that in some cases, a measurement of one particle would lead to an incorrect prediction of the trajectory of the entangled particle. They coined the term "surreal trajectories" to describe them.

In the most recent experiment, Steinberg and colleagues showed that the surrealism was a consequence of non-locality - the fact that the particles were able to influence one another instantaneously at a distance. In fact, the "incorrect" predictions of trajectories by the entangled photon were actually a consequence of where in their course the entangled particles were measured. Considering both particles together, the measurements made sense and were consistent with real trajectories.

Steinberg points out that both the standard interpretation of quantum mechanics and the De Broglie-Bohm interpretation are consistent with experimental evidence, and are mathematically equivalent. But it is helpful in some circumstances to visualize real trajectories, rather than wave function collapses, he says. [8]

Physicists discover easy way to measure entanglement—on a sphere



Entanglement on a sphere: This Bloch sphere shows entanglement for the one-root state ρ and its radial state ρc. The color on the sphere corresponds to the value of the entanglement, which is determined by the distance from the root state z, the point at which there is no entanglement. The closer to z, the less the entanglement (red); the further from z, the greater the entanglement (blue). Credit: Regula and Adesso. ©2016 American Physical Society

Now in a new paper to be published in Physical Review Letters, mathematical physicists Bartosz Regula and Gerardo Adesso at The University of Nottingham have greatly simplified the problem of measuring entanglement.

To do this, the scientists turned the difficult analytical problem into an easy geometrical one. They showed that, in many cases, the amount of entanglement between states corresponds to the distance between two points on a Bloch sphere, which is basically a normal 3D sphere that physicists use to model quantum states.

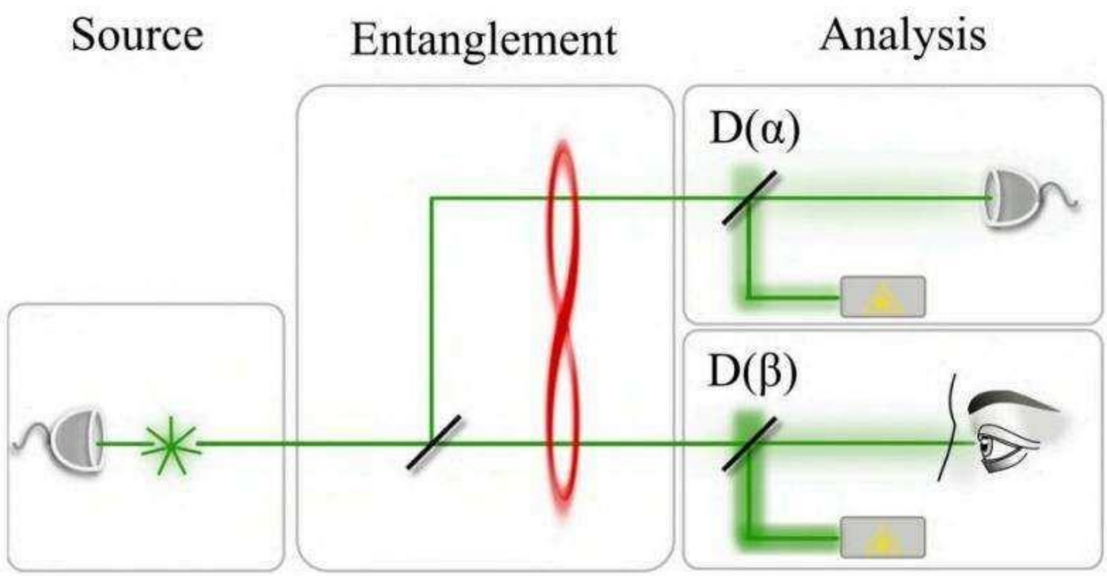
As the scientists explain, the traditionally difficult part of the math problem is that it requires finding the optimal decomposition of mixed states into pure states. The geometrical approach completely eliminates this requirement by reducing the many possible ways that states could decompose down to a single point on the sphere at which there is zero entanglement. The approach requires that there be only one such point, or "root," of zero entanglement, prompting the physicists to describe the method as "one root to rule them all."

The scientists explain that the "one root" property is common among quantum states and can be easily verified, transforming a formidable math problem into one that is trivially easy. They demonstrated that the new approach works for many types of two-, three- and four-qubit entangled states.

"This method reveals an intriguing and previously unexplored connection between the quantum features of a state and classical geometry, allowing all one-root states to enjoy a convenient visual representation which considerably simplifies the study and understanding of their properties," the researchers explained.

The simple way of measuring a state's entanglement could have applications in many technological areas, such as quantum cryptography, computation, and communication. It could also provide insight into understanding the foundations of thermodynamics, condensed matter physics, and biology. [7]

An idea for allowing the human eye to observe an instance of entanglement



Scheme of the proposal for detecting entanglement with the human eye. Credit: arXiv:1602.01907

Entanglement, is of course, where two quantum particles are intrinsically linked to the extent that they actually share the same existence, even though they can be separated and moved apart. The idea was first proposed nearly a century ago, and it has not only been proven, but researchers routinely cause it to occur, but, to date, not one single person has every actually seen it happen—they only know it happens by conducting a series of experiments. It is not clear if anyone has ever actually tried to see it happen, but in this new effort, the research trio claim to have found a way to make it happen—if only someone else will carry out the experiment on a willing volunteer.

The idea involves using a beam splitter and two beans of light—an initial beam of coherent photons fired at the beam splitter and a secondary beam of coherent photons that interferes with the photons in the first beam causing a change of phase, forcing the light to be reflected rather than transmitted. In such a scenario, the secondary beam would not need to be as intense as the first, and could in fact be just a single coherent photon—if it were entangled, it could be used to allow a person to see the more powerful beam while still preserving the entanglement of the original photon.

The researchers suggest the technology to carry out such an experiment exists today, but also acknowledge that it would take a special person to volunteer for such an assignment because to prove that they had seen entanglement taking place would involve shooting a large number of photons in series, into a person's eye, whereby the resolute volunteer would announce whether they had seen the light on the order of thousands of times. [6]

Quantum entanglement

Measurements of physical properties such as position, momentum, spin, polarization, etc. performed on entangled particles are found to be appropriately correlated. For example, if a pair of particles is generated in such a way that their total spin is known to be zero, and one particle is found to have clockwise spin on a certain axis, then the spin of the other particle, measured on the same axis, will be found to be counterclockwise. Because of the nature of quantum measurement, however, this behavior gives rise to effects that can appear paradoxical: any measurement of a property of a particle can be seen as acting on that particle (e.g. by collapsing a number of superimposed states); and in the case of entangled particles, such action must be on the entangled system as a whole. It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances. [4]

The Bridge

The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [1]

Accelerating charges

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field. In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion. The same thing happens on the atomic scale giving a dp impulse difference and a dx way difference between the different part of the not point like particles.

Relativistic effect

Another bridge between the classical and quantum mechanics in the realm of relativity is that the charge distribution is lowering in the reference frame of the accelerating charges linearly: ds/dt = at (time coordinate), but in the reference frame of the current it is parabolic: $s = a/2\ t^2$ (geometric coordinate).

Heisenberg Uncertainty Relation

In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass.

This means that the electron and proton are not point like particles, but has a real charge distribution.

Wave – Particle Duality

The accelerating electrons explains the wave – particle duality of the electrons and photons, since the elementary charges are distributed on delta x position with delta p impulse and creating a wave packet of the electron. The photon gives the electromagnetic particle of the mediating force of the electrons electromagnetic field with the same distribution of wavelengths.

Atomic model

The constantly accelerating electron in the Hydrogen atom is moving on the equipotential line of the proton and it's kinetic and potential energy will be constant. Its energy will change only when it is changing its way to another equipotential line with another value of potential energy or getting free with enough kinetic energy. This means that the Rutherford-Bohr atomic model is right and only that changing acceleration of the electric charge causes radiation, not the steady acceleration. The steady acceleration of the charges only creates a centric parabolic steady electric field around the charge, the magnetic field. This gives the magnetic moment of the atoms, summing up the proton and electron magnetic moments caused by their circular motions and spins.

The Relativistic Bridge

Commonly accepted idea that the relativistic effect on the particle physics it is the fermions' spin - another unresolved problem in the classical concepts. If the electric charges can move only with accelerated motions in the self maintaining electromagnetic field, once upon a time they would reach the velocity of the electromagnetic field. The resolution of this problem is the spinning particle, constantly accelerating and not reaching the velocity of light because the acceleration is radial. One origin of the Quantum Physics is the Planck Distribution Law of the electromagnetic oscillators, giving equal intensity for 2 different wavelengths on any temperature. Any of these two wavelengths will give equal intensity diffraction patterns, building different asymmetric constructions, for example proton - electron structures (atoms), molecules, etc. Since the particles are centers of diffraction patterns they also have particle – wave duality as the electromagnetic waves have. [2]

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T-symmetry breaking!!! This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction.

Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

Van Der Waals force

Named after the Dutch scientist Johannes Diderik van der Waals – who first proposed it in 1873 to explain the behaviour of gases – it is a very weak force that only becomes relevant when atoms and molecules are very close together. Fluctuations in the electronic cloud of an atom mean that it will have an instantaneous dipole moment. This can induce a dipole moment in a nearby atom, the result being an attractive dipole–dipole interaction.

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The frequency dependence of mass

Since $E = hv$ and $E = mc^2$, $m = hv / c^2$ that is the m depends only on the v frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [2]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate Mp=1840 Me. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The Higgs boson

By March 2013, the particle had been proven to behave, interact and decay in many of the expected ways predicted by the Standard Model, and was also tentatively confirmed to have + parity and zero spin, two fundamental criteria of a Higgs boson, making it also the first known scalar particle to be discovered in nature, although a number of other properties were not fully proven and some partial results do not yet precisely match those expected; in some cases data is also still awaited or being analyzed.

Since the Higgs boson is necessary to the W and Z bosons, the dipole change of the Weak interaction and the change in the magnetic effect caused gravitation must be conducted. The Wien law is also important to explain the Weak interaction, since it describes the T_{max} change and the diffraction patterns change. [2]

Higgs mechanism and Quantum Gravity

The magnetic induction creates a negative electric field, causing an electromagnetic inertia. Probably it is the mysterious Higgs field giving mass to the charged particles? We can think about the photon as an electron-positron pair, they have mass. The neutral particles are built from negative and positive charges, for example the neutron, decaying to proton and electron. The wave – particle duality makes sure that the particles are oscillating and creating magnetic induction as an inertial mass, explaining also the relativistic mass change. Higher frequency creates stronger magnetic induction, smaller frequency results lesser magnetic induction. It seems to me that the magnetic induction is the secret of the Higgs field.

In particle physics, the Higgs mechanism is a kind of mass generation mechanism, a process that gives mass to elementary particles. According to this theory, particles gain mass by interacting with the Higgs field that permeates all space. More precisely, the Higgs mechanism endows gauge bosons in a gauge theory with mass through absorption of Nambu–Goldstone bosons arising in spontaneous symmetry breaking.

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The spontaneous symmetry breaking of the underlying local symmetry triggers conversion of components of this Higgs field to Goldstone bosons which interact with (at least some of) the other fields in the theory, so as to produce mass terms for (at least some of) the gauge bosons. This mechanism may also leave behind elementary scalar (spin-0) particles, known as Higgs bosons.

In the Standard Model, the phrase "Higgs mechanism" refers specifically to the generation of masses for the $W^{\pm}$, and Z weak gauge bosons through electroweak symmetry breaking. The Large Hadron Collider at CERN announced results consistent with the Higgs particle on July 4, 2012 but stressed that further testing is needed to confirm the Standard Model.

What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

The Secret of Quantum Entanglement

The Secret of Quantum Entanglement that the particles are diffraction patterns of the electromagnetic waves and this way their quantum states every time is the result of the quantum state of the intermediate electromagnetic waves. [2] When one of the entangled particles wave function is collapses by measurement, the intermediate photon also collapses and transforms its state to the second entangled particle giving it the continuity of this entanglement. Since the accelerated charges are self-maintaining their potential locally causing their acceleration, it seems that they entanglement is a spooky action at a distance.

Conclusions

The accelerated charges self-maintaining potential shows the locality of the relativity, working on the quantum level also.

The Secret of Quantum Entanglement that the particles are diffraction patterns of the electromagnetic waves and this way their quantum states every time is the result of the quantum state of the intermediate electromagnetic waves.

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions.

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