Deep Learning Disease Mutations

A research team led by Professor Hongzhe Sun from the Department of Chemistry at the University of Hong Kong (HKU), in collaboration with Professor Junwen Wang from Mayo Clinic, Arizona in the United States (a former HKU colleague), implemented a robust deep learning approach to predict disease-associated mutations of the metal-binding sites in a protein. [33]

Researchers at the US Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) employed a suite of deep-learning techniques to identify and observe these temporary yet notable structures. [32]

As part of a team of scientists from IBM and New York University, my colleagues and I are looking at new ways AI could be used to help ophthalmologists and optometrists further utilize eye images, and potentially help to speed the process for detecting glaucoma in images. [31]

A team of EPFL scientists has now written a machine-learning program that can predict, in record time, how atoms will respond to an applied magnetic field. [30]

Researchers from the University of Luxembourg, Technische Universität Berlin, and the Fritz Haber Institute of the Max Planck Society have combined machine learning and quantum mechanics to predict the dynamics and atomic interactions in molecules. [29]

For the first time, physicists have demonstrated that machine learning can reconstruct a quantum system based on relatively few experimental measurements. [28]

AlphaZero plays very unusually; not like a human, but also not like a typical computer. Instead, it plays with "real artificial" intelligence. [27]

Predictions for an AI-dominated future are increasingly common, but Antoine Blondeau has experience in reading, and arguably manipulating, the runes—he helped develop technology that evolved into predictive texting and Apple's Siri. [26]

Artificial intelligence can improve health care by analyzing data from apps, smartphones and wearable technology. [25]

Now, researchers at Google's DeepMind have developed a simple algorithm to handle such reasoning—and it has already beaten humans at a complex image comprehension test. [24]

A marimba-playing robot with four arms and eight sticks is writing and playing its own compositions in a lab at the Georgia Institute of Technology. The pieces are generated using artificial intelligence and deep learning. [23]

Now, a team of researchers at MIT and elsewhere has developed a new approach to such computations, using light instead of electricity, which they say could vastly improve the speed and efficiency of certain deep learning computations. [22]

Physicists have found that the structure of certain types of quantum learning algorithms is very similar to their classical counterparts—a finding that will help scientists further develop the quantum versions. [21]

We should remain optimistic that quantum computing and AI will continue to improve our lives, but we also should continue to hold companies, organizations, and governments accountable for how our private data is used, as well as the technology's impact on the environment. [20]

It's man vs machine this week as Google's artificial intelligence programme AlphaGo faces the world's top-ranked Go player in a contest expected to end in another victory for rapid advances in AI. [19]

Google's computer programs are gaining a better understanding of the world, and now it wants them to handle more of the decision-making for the billions of people who use its services. [18]

Microsoft on Wednesday unveiled new tools intended to democratize artificial intelligence by enabling machine smarts to be built into software from smartphone games to factory floors. [17]

The closer we can get a machine translation to be on par with expert human translation, the happier lots of people struggling with translations will be. [16]

Researchers have created a large, open source database to support the development of robot activities based on natural language input. [15]

A pair of physicists with ETH Zurich has developed a way to use an artificial neural network to characterize the wave function of a quantum many-body system. [14]

A team of researchers at Google's DeepMind Technologies has been working on a means to increase the capabilities of computers by combining aspects of data processing and artificial intelligence and have come up with what they are calling a differentiable neural computer (DNC.) In their paper published in the journal Nature, they describe the work they are doing and where they believe it is headed. To make the work more accessible to the public team members,
Alexander Graves and Greg Wayne have posted an explanatory page on the DeepMind website. [13]

Nobody understands why deep neural networks are so good at solving complex problems. Now physicists say the secret is buried in the laws of physics. [12]

A team of researchers working at the University of California (and one from Stony Brook University) has for the first time created a neural-network chip that was built using just memristors. In their paper published in the journal Nature, the team describes how they built their chip and what capabilities it has. [11]

A team of researchers used a promising new material to build more functional memristors, bringing us closer to brain-like computing. Both academic and industrial laboratories are working to develop computers that operate more like the human brain. Instead of operating like a conventional, digital system, these new devices could potentially function more like a network of neurons.
[10]

Cambridge Quantum Computing Limited (CQCL) has built a new Fastest Operating System aimed at running the futuristic superfast quantum computers. [9]

IBM scientists today unveiled two critical advances towards the realization of a practical quantum computer. For the first time, they showed the ability to detect and measure both kinds of quantum errors simultaneously, as well as demonstrated a new, square quantum bit circuit design that is the only physical architecture that could successfully scale to larger dimensions. [8] Physicists at the Universities of Bonn and Cambridge have succeeded in linking two completely different quantum systems to one another. In doing so, they have taken an important step forward on the way to a quantum computer. To accomplish their feat the researchers used a method that seems to function as well in the quantum world as it does for us people: teamwork. The results have now been published in the "Physical Review Letters". [7]

While physicists are continually looking for ways to unify the theory of relativity, which describes large-scale phenomena, with quantum theory, which describes small-scale phenomena, computer scientists are searching for technologies to build the quantum computer.

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 and making possible to build the Quantum Computer.

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Author: George Rajna

Preface

While physicists are continually looking for ways to unify the theory of relativity, which describes large-scale phenomena, with quantum theory, which describes small-scale phenomena, computer scientists are searching for technologies to build the quantum computer.

Both academic and industrial laboratories are working to develop computers that operate more like the human brain. Instead of operating like a conventional, digital system, these new devices could potentially function more like a network of neurons. [10]

So far, we just have heard about Quantum computing that could make even complex calculations trivial, but there are no practical Quantum computers exist. However, the dream of Quantum computers could become a reality in coming future. [9]

Using a square lattice, IBM is able to detect both types of quantum errors for the first time. This is the best configuration to add more qubits to scale to larger systems. [8]

Australian engineers detect in real-time the quantum spin properties of a pair of atoms inside a silicon chip, and disclose new method to perform quantum logic operations between two atoms. [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.

Using deep learning to predict disease-associated mutations

During the past years, artificial intelligence (AI)—the capability of a machine to mimic human behavior—has become a key player in high-tech areas like drug development projects. AI tools help scientists to uncover the secret behind the big biological data using optimized computational algorithms. AI methods such as deep neural network improves decision making in biological and chemical applications i.e., prediction of disease-associated proteins, discovery of novel biomarkers and de novo design of small molecule drug leads. These state-of-the-art approaches help scientists to develop a potential drug more efficiently and economically.

A research team led by Professor Hongzhe Sun from the Department of Chemistry at the University of Hong Kong (HKU), in collaboration with Professor Junwen Wang from Mayo Clinic, Arizona in the United States (a former HKU colleague), implemented a robust deep learning approach to predict disease-associated mutations of the metal-binding sites in a protein. This is the first deep learning approach for the prediction of disease-associated metal-relevant site mutations in metalloproteins, providing a new platform to tackle human diseases. The research findings were recently published in a top scientific journal *Nature Machine Intelligence*.

Metal ions play pivotal roles either structurally or functionally in the (patho)physiology of human biological systems. Metals such as zinc, iron and copper are essential for all life, and their concentration in cells must be strictly regulated. A deficiency or an excess of these physiological metal ions can cause severe disease in humans. It was discovered that mutations in the human genome are strongly associated with different diseases. If these mutations happen in the coding region of DNA, they might disrupt metal-binding sites of the proteins and consequently initiate severe diseases in humans. Understanding of disease-associated mutations at the metal-binding sites of proteins will facilitate discovery of new drugs.

The team first integrated omics data from different databases to build a comprehensive training dataset. By looking at the statistics from the collected data, the team found that different metals have different disease associations. A mutation in zinc-binding sites has a major role in breast, liver, kidney, immune system and prostate diseases. By contrast, the mutations in calcium- and magnesium-binding sites are associated with muscular and immune system diseases, respectively. For iron-binding sites, mutations are more associated with metabolic diseases. Furthermore, mutations of manganese- and copper-binding sites are associated with cardiovascular diseases with the latter being associated with nervous system disease as well.

The researchers used a novel approach to extract spatial features from the metal binding sites using an energy-based affinity grid map. These spatial features have been merged with physicochemical sequential features to train the model. The final results show that using the spatial features enhanced the performance of the prediction with an area under the curve (AUC) of 0.90 and an accuracy of 0.82. Given the limited advanced techniques and platforms in the field of metallomics and metalloproteins, the proposed deep learning approach offers a method to integrate experimental data with bioinformatics analysis. The approach will help scientist to predict DNA mutations which are associated with diseases like cancer, cardiovascular diseases and genetic disorders.

Professor Sun said: "Machine learning and AI play important roles in the current biological and chemical sciences. In my group we worked on metals in biology and medicine using an integrative omics approach including metallomics and metalloproteomics, and we already produced a large amount of valuable data using in vivo/vitro experiments. We are now developing an artificial intelligence approach based on deep learning to turn these raw data into valuable knowledge, leading us to uncover secrets behind the diseases and to fight them. I believe this novel deep learning approach can be used in other projects, which is ongoing in our laboratory." [33]

Modified deep-learning algorithms unveil features of shape-shifting proteins

Using artificial neural networks designed to emulate the inner workings of the human brain, deep-learning algorithms deftly peruse and analyze large quantities of data. Applying this technique to science problems can help unearth historically elusive solutions.

One such challenge involves a biophysical phenomenon known as protein folding. Although researchers know that proteins must morph into specific 3-D shapes via this process to function properly, the intricacies of intermediate stages between the initial unfolded state and the final folded state are both critically important to their eventual purpose and notoriously difficult to characterize.

Researchers at the US Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) employed a suite of deep-learning techniques to identify and observe these temporary yet notable structures. They published their findings in *BMC Bioinformatics*.

The team adapted an existing deep-learning algorithm known as a convolutional variational autoencoder (CVAE), which automatically extracted relevant information about protein folding configurations from molecular dynamics (MD) simulations. The researchers ran these simulations on Summitdev, a small-scale precursor to Summit, currently the world's most powerful supercomputer, which is located at the Oak Ridge Leadership Computing Facility (OLCF), a DOE Office of Science User Facility at ORNL.

By studying the folding pathways of three different proteins—namely Fs-peptide, villin head piece, and BBA—the researchers computationally compared multiple protein folding mechanisms. They relied on datasets obtained from other research groups that have run extensive simulations to examine these pathways. In each case, the CVAE revealed many intermediate stages that serve as "guideposts" to help the team navigate the folding process from start to finish while observing latent facets of protein behavior.

"We took the protein folding trajectories compiled from running MD simulations and fed them into the deep-learning network, which automatically uncovered the relevant guideposts for various proteins," said Arvind Ramanathan, a former ORNL researcher who led this effort.

"These relevant guideposts are picked in a completely unsupervised manner from the high dimensional folding trajectories in such a way that only biophysically relevant features important to that particular system are chosen," added ORNL computational scientist Debsindhu Bhowmik, who implemented the CVAE algorithm customized for the protein systems.

Ramanathan compared this ability to pinpoint transitional protein states to a driver choosing logical pitstops en route from one region to another.

"If you are driving from Knoxville in East Tennessee all the way to Memphis in West Tennessee, then the natural stopping point is Nashville," Ramanathan said. "Just as there are many different routes you can take to reach a road trip destination, there are many different paths proteins take to fold into their final shapes."

However, even the most minute change to these folding pathways can cause proteins to "misfold" into dysfunctional shapes. Misfolding is often attributed as a leading factor in the development of diseases including Alzheimer's, cardiovascular disorders, and diabetes.

"The overall shape of a protein determines its function, so some small perturbation in that shape can produce a misfolded protein and lead to serious medical conditions," Ramanathan said.

With this capacity to differentiate between correctly folded and misfolded proteins, the researchers could gain additional insights into why proteins misfold, how other factors contribute to the development of deadly diseases, and which treatment regimens are most likely to prevent or cure them. For example, identifying a problematic site in a particular protein might indicate the need for planting a binding agent or drug to change that protein's behavior.

Reaching this goal will require increasingly precise techniques, which the team hopes to develop by modeling multiple machine-learning algorithms on NVIDIA DGX-2 boxes, computing systems that enable novel artificial intelligence applications. The DGX-2s were recently installed at ORNL's Compute and Data Environment for Science (CADES), which provides ORNL staff with the infrastructure and expertise needed to complete data-intensive projects.

The researchers focused on optimizing reinforcement-learning algorithms, which perform tasks without preliminary training, then steadily learn from experience to maximize rewards and minimize negative outcomes. One prominent example, Google's AlphaGo computer program, defeated a world champion in the board game Go. Similar reinforcement-learning algorithms are also embedded in arcade and console video games, and the team plans to customize this method for scientific purposes, including gathering and interpreting protein folding data.

"One way to steer MD simulations is to use these powerful reinforcement-learning techniques, but adapting them for these types of simulations requires quite a bit of work and computing power," Ramanathan said.

To improve the algorithms, the team had to optimize hyperparameters, which are parameters set before algorithms start making decisions. Running multiple algorithms on the DGX-2s at once allowed the team to quickly compile data they used to develop HyperSpace, a specialized software package that simplifies and streamlines the process of hyperparameter optimization.

The researchers presented this work at the 2018 High Performance Machine Learning Workshop, an annual event where machine learning, artificial intelligence, and high-performance computing experts gather to discuss experiences and share expertise.

"We found that, for a variety of machine-learning algorithms such as deep-learning algorithms, convolutional neural networks, and reinforcement-learning algorithms, HyperSpace is quite successful and outperforms comparable models," Ramanathan said.

Now, the scientists are building a scalable workflow to benefit future research involving protein folding and other biological phenomena, some of which they plan to study on Summit.

"Although we have focused mostly on protein folding so far, we are actively probing other questions such as how two separate proteins interact with each other," Ramanathan said. [32]

Deep learning for glaucoma detection

Glaucoma is the second leading cause of blindness in the world, impacting approximately 2.7 million people in the U.S alone. It is a complex set of diseases and, if left untreated, can lead to blindness. It's a particularly large issue in Australia, where only 50 percent of all people who have it are actually diagnosed and receive the treatment they need.

As part of a team of scientists from IBM and New York University, my colleagues and I are looking at new ways AI could be used to help ophthalmologists and optometrists further utilize eye images, and potentially help to speed the process for detecting glaucoma in images. In a recent paper, we detail a new deep learning framework that detects glaucoma directly from raw optical coherence tomographic (OCT) imaging, a method which uses light waves to take cross-section pictures of the retina. This method achieved an accuracy rate of 94 percent, without any additional segmentation or scrubbing of the data, which is usually time-consuming.

Currently, glaucoma is diagnosed using a variety of tests, such as intraocular pressure measurements and visual field tests, as well as fundus and OCT imaging. OCT provides an efficient way to visualize and quantify structures in the eye, namely the retinal nerve fibre layer (RNFL), which changes with progression of the disease.

Although this approach works well, it requires an additional process to quantify the RNFL in OCT images. These techniques also typically clean up the input data in a variety of ways, such as flipping all eyes into the same orientation (left or right) in order to reduce variability in the data to improve the performance of the classifiers. Our approach removes these additional steps, indicating that these potentially time-consuming stages are not required for the detection of glaucoma.

Ultimately, when normalised by a false positive rate, in a cohort of 624 subjects (217 healthy and 432 glaucoma patients), our new approach, founded in deep learning, correctly detects glaucomatous eyes in 94 percent of cases, while previously mentioned techniques only found this in 86 percent of cases. We believe this improved accuracy is a result of eliminating errors in the automated segmentation of structures in images as well as the inclusion of regions of the image that are not currently utilised clinically for this purpose.

Additionally, contrary to the current trend in AI research that uses larger and deeper networks, the network we used was a small 5-layer network because medical data is not as easily accessible due its confidential nature. This data scarcity makes the use of large networks impractical in many medical applications. Even in research, we are sometimes seeing that "less is more," and the training of these algorithms on smaller networks allows them to run with greater efficiency.

This is just one facet of our research in applying AI for the eye. In a recently announced new collaboration, IBM Research and George & Matilda (G&M) will leverage G&M's robust data set of anonymous clinical data and imaging studies to explore methods to use deep learning models and imaging analytics to support clinicians in the identification and detection of eye disease—including glaucoma—in images. Researchers will also look to investigate the potential biomarkers of glaucoma, which could help in better understanding disease progression. [31]

AI and NMR spectroscopy determine atoms configuration in record time

Many drugs today are produced as powdered solids. But to fully understand how the active ingredients will behave once inside the body, scientists need to know their exact atomic-level structure. For instance, the way molecules are arranged inside a crystal has a direct impact on a compound's properties, such as its solubility. Researchers are therefore working hard to develop technologies that can easily identify the exact crystal structures of microcrystalline powders.

A team of EPFL scientists has now written a machine-learning program that can predict, in record time, how atoms will respond to an applied magnetic field. This can be combined with nuclear magnetic resonance (NMR) spectroscopy to determine the exact location of atoms in complex organic compounds. This can be of huge benefit to pharmaceutical companies, which must carefully monitor their molecules' structures to meet requirements for patient safety. Their research has been published in *Nature Communications*.

Breakneck speeds with AI

NMR spectroscopy is a well-known and highly efficient method for probing the magnetic fields between atoms and determining how neighboring atoms interact with each other. However, full crystal structure determination by NMR spectroscopy requires extremely complicated, time-consuming calculations involving quantum chemistry – nearly impossible for molecules with very intricate structures.

But the program developed at EPFL can overcome these obstacles. The scientists trained their AI model on molecular structures taken from structural databases. "Even for relatively simple molecules, this model is almost 10,000 times faster than existing methods, and the advantage grows tremendously when considering more complex compounds," says Michele Ceriotti, head of the Laboratory of Computational Science and Modeling at EPFL's School of Engineering and co-author of the study. "To predict the NMR signature of a crystal with nearly 1,600 atoms, our technique – ShiftML – requires about six minutes; the same feat would have taken 16 years with conventional techniques."

This new program will make it possible to use completely different approaches that will be faster and allow access to larger molecules. "This is really exciting because the massive acceleration in computation times will allow us to cover much larger conformational spaces and correctly determine structures where it was just not previously possible. This puts most of the complex contemporary drug molecules within reach," says Lyndon Emsley, head of the Laboratory of Magnetic Resonance at EPFL's School of Basic Sciences and co-author of the study.

The program is now freely available online. "Anyone can upload a molecule and get its NMR signature in just a few minutes," says Ceriotti. [30]

Researchers study interactions in molecules using AI

Researchers from the University of Luxembourg, Technische Universität Berlin, and the Fritz Haber Institute of the Max Planck Society have combined machine learning and quantum mechanics to predict the dynamics and atomic interactions in molecules. The new approach allows for a degree of precision and efficiency that has never been achieved before.

Molecular dynamics simulations are used in natural and material science to predict the properties and behavior of different materials. In the past, these simulations were usually based on mechanistic models that are unable to integrate important insights from the quantum mechanics. This work now published in *Nature Communications* substantially improves the prediction capabilities of modern atomistic modeling in chemistry, biology, and the material sciences.

Exact knowledge about the molecular dynamics of a substance, in other words precise knowledge of the possible states and interactions of single atoms in a molecule, enables us to not only understand many chemical and physical reactions but also to make use of these. "Machine learning techniques have dramatically altered work in many disciplines, but up until now, little use has been made of them in molecular dynamics simulations," says Klaus-Robert Müller, Professor of machine learning at TU Berlin. The problem: Most standard algorithms have been developed with the understanding that the amount of data to be processed is of no relevance. "This doesn't apply, however, for accurate quantum mechanical calculations of a molecule, where every single data point is crucial and the individual calculation for larger molecules can take several weeks or even months. The enormous computational resources required to do this has meant that precise molecular dynamics simulations have not been possible to date," explains Alexandre Tkatchenko, professor of theoretical chemical physics at the University of Luxembourg.

It is precisely this problem which the researchers have now solved by integrating physical laws into machine learning techniques. "The trick consists in not calculating all potential possible states of molecular dynamics with machine learning techniques, but rather only those which do not result from known physical laws or the application of symmetry operations", explains Professor Alexandre Tkatchenko.

On the one hand, the newly developed algorithms use natural mathematical symmetries within molecules. Among the things they recognise are axes of symmetry which do not alter the physical characteristics of the molecule. As a result, these data points need only be calculated once, rather than several times, which greatly reduces the complexity of the calculation. Additionally, the learning techniques use the physical law of the conservation of energy.

Through this innovative approach of allowing the machine learning techniques employed to "incorporate" physical laws before learning to calculate the molecular dynamics, the research team has succeeded in reconciling the two contradicting aspects of high precision and data efficiency. "These special algorithms permit the process to focus on the complex problems of the simulation, rather than using computer performance for the reconstruction of trivial relationships between data points. As such, this research demonstrates the great potential of combining AI and chemistry or other natural sciences", Klaus-Robert Müller says, explaining the significance of the project. [29]

Artificial intelligence techniques reconstruct mysteries of quantum systems

The same techniques used to train self-driving cars and chess-playing computers are now helping physicists explore the complexities of the quantum world.

For the first time, physicists have demonstrated that machine learning can reconstruct a quantum system based on relatively few experimental measurements. This method will allow scientists to thoroughly probe systems of particles exponentially faster than conventional, brute-force techniques. Complex systems that would require thousands of years to reconstruct with previous methods could be wholly analyzed in a matter of hours.

The research will benefit the development of quantum computers and other applications of quantum mechanics, the researchers report February 26 in *Nature Physics*.

"We have shown that machine intelligence can capture the essence of a quantum system in a compact way," says study co-author Giuseppe Carleo, an associate research scientist at the Center for Computational Quantum Physics at the Flatiron Institute in New York City. "We can now effectively extend the capabilities of experiments."

Carleo, who conducted the research while a lecturer at ETH Zurich, was inspired by AlphaGo. This computer program used machine learning to outplay the world champion of the Chinese board game Go in 2016. "AlphaGo was really impressive," he says, "so we started asking ourselves how we could use those ideas in quantum physics."

Systems of particles such as electrons can exist in lots of different configurations, each with a particular probability of occurring. Each electron, for instance, can have either an upward or downward spin, similar to Schrödinger's cat being either dead or alive in the famous thought experiment. In the quantum realm, unobserved systems don't exist as any one of these arrangements. Instead, the system may be thought of as being is in all possible configurations simultaneously.

When measured, the system collapses into one configuration, just like Schrödinger's cat is either dead or alive once you open its box. This quirk of quantum mechanics means that you can never observe the entire complexity of a system in a single experiment. Instead, experimentalists conduct the same measurements over and over until they can determine the state of the whole system.

That method works well for simple systems containing only a few particles. But "things get nasty with a lot of particles," Carleo says. As the number of particles increases, the complexity skyrockets. If only considering that each electron can have either spin up or down, a system of five electrons has 32 possible configurations. A system of 100 electrons has more than 1 million trillion trillion.

The entanglement of particles further complicates matters. Through quantum entanglement, independent particles become intertwined and can no longer be treated as purely separate entities even when physically separated. This entanglement alters the probability of different configurations.

Conventional methods, therefore, just aren't feasible for complex quantum systems.

Giacomo Torlai of the University of Waterloo and the Perimeter Institute in Canada, Carleo and colleagues circumvented these limitations by tapping machine learning techniques. The researchers fed experimental measurements of a quantum system to a software tool based on artificial neural networks. The software learns over time and attempts to mimic the system's behavior. Once the software ingests enough data, it can accurately reconstruct the complete quantum system.

The researchers tested the software using mock experimental datasets based on different sample quantum systems. In these tests, the software far surpassed conventional methods. For eight electrons, each with spin up or down, the software could accurately reconstruct the system with only around 100 measurements. For comparison, a conventional brute-force method required almost 1 million measurements to reach the same level of accuracy. The new technique can also handle much larger systems. In turn, this ability can help scientists validate that a quantum computer is correctly set up and that any quantum software would run as intended, the researchers suggest.

Capturing the essence of complex quantum systems with compact artificial neural networks has other far-reaching consequences. Center for Computational Quantum Physics co-director Andrew Millis notes that the ideas provide an important new approach to the center's ongoing development of novel methods for understanding the behavior of interacting quantum systems, and connect with work on other quantum physics-inspired machine learning approaches.

Besides applications to fundamental research, Carleo says that the lessons the team learned as they blended machine learning with ideas from quantum physics could improve general-purpose applications of artificial intelligence as well. "We could use the methods we developed here in other contexts," he says. "Someday we might have a self-driving car inspired by quantum mechanics, who knows." [28]

AlphaZero just wants to play

Artificial intelligence is continually hyped up, but disappears from view again just as quickly. Roger Wattenhofer explains why that might soon change.

Over the last 60 years, artificial intelligence researchers have continually made futuristic predictions. For example, they announced that a computer would become a chess grandmaster. It was expected by 1968; it happened around 30 years later. Even more optimistic were the predictions that computers would be able to perform any and every human task by 1985 – but even today, we're still a long way from that being the case.

A history of ups and downs

Disillusionment often followed, large-scale research programmes were scrapped, and a series of AI winters set in. Eventually, researchers didn't even want to talk about "artificial intelligence", preferring instead to study the more modest field of "machine learning".

At the turn of the millennium came a few successes: IBM's Deep Blue defeated Garry Kasparov at chess. Critics complained that chess was not a real test of intelligence, and repeated John Searle's Chinese room argument: Deep Blue didn't really understand the game, it simply calculated very quickly. A few years later, a car from Stanford succeeded in navigating autonomously, but even that was only only in the desert. Finally, IBM's Watson won the quiz show Jeopardy! – but was it truly down to intelligence, or was it just a case of advanced googling?

Wolf cried too often?

I think that AI research and its advocates have cried wolf too often – meaning that now, people don't tend to see the value of real successes and genuine breakthroughs. But the wolf is really here, and it has a name: AlphaZero.

AlphaZero, a computer programme from DeepMind, can teach itself skills such as chess. Since Deep Blue, chess programmes have been continuously refined. The best programmes, such as Stockfish, reached such a high level years ago that humans stand no chance against them.

Stockfish knows a lot of chess theory, and is familiar with every game ever played. AlphaZero only knew the rules of chess; it learned the game by playing against itself for a few hours. It initially made a lot of beginner's mistakes, but after four hours of self-training, it defeated Stockfish. (There are a few valid objections that discuss the use of hardware and unfair competition rules.)

The professional game will change

I recommend that anyone who understands anything about chess watch the tenth game against Stockfish. AlphaZero plays very unusually; not like a human, but also not like a typical computer. Instead, it plays with "real artificial" intelligence. As AlphaZero began by knowing no chess theory, it had to develop its own theories. Grandmaster Daniel King thinks that AlphaZero will change chess theory and the professional game as soon as it is publicly accessible.

In a sense, AlphaZero is more human than a normal computer. The deep network structure is reminiscent of a human brain, and it calculates more slowly: per game, it assesses thousands of times fewer moves than Stockfish. It would be interesting to see how a game of human vs. AlphaZero would play out, if AlphaZero were slowed down to human speed. And AlphaZero can do more than just play chess. It also knows other games that it has taught itself.

I, for one, am impressed. AlphaZero's performance shows that we have to take artificial intelligence seriously, and proves that we are witnessing an enormous change. I am convinced that AlphaZero & Co. will have a lasting effect on society. [27]

AI revolution will be all about humans, says Siri trailblazer

Predictions for an AI-dominated future are increasingly common, but Antoine Blondeau has experience in reading, and arguably manipulating, the runes—he helped develop technology that evolved into predictive texting and Apple's Siri.

"In 30 years the world will be very different," he says, adding: "Things will be designed to meet your individual needs."

Work, as we know it, will be redundant, he says—visual and sensory advances in robotics will see smart factories make real time decisions requiring only human oversight rather than workers, while professions such as law, journalism, accounting and retail will be streamlined with AI doing the grunt work.

Healthcare is set for a revolution, with individuals holding all the data about their general health and AI able to diagnose ailments, he explains.

Blondeau says: "If you have a doctor's appointment, it will be perhaps for the comfort of talking things through with a human, or perhaps because regulation will dictate a human needs to dispense medicine. But you won't necessarily need the doctor to tell you what is wrong."

The groundwork has been done: Amazon's Alexa and Google Home are essentially digital butlers that can respond to commands as varied as ordering pizza to managing appliances, while Samsung is working on a range of 'smart' fridges, capable of giving daily news briefings, ordering groceries, or messaging your family at your request.

Leading media companies are already using 'AI journalists' to produce simple economics and sports stories from data and templates created by their human counterparts.

Blondeau's firm Sentient Technologies has already successfully used AI traders in the financial markets.

In partnership with US retailer , it created an interactive 'smart shopper', which uses an algorithm that picks up information from gauging not just what you like, but what you don't, offering suggestions in the way a real retail assistant would.

In healthcare, the firm worked with America's MIT to invent an AI nurse able to assess patterns in blood pressure data from thousands of patients to correctly identify those developing sepsis—a catastrophic immune reaction—30 minutes before the outward onset of the condition more than 90 percent of the time in trials.

"It's a critical window that doctors say gives them the extra time to save lives," Blondeau says, but concedes that bringing such concepts to the masses is difficult.

"The challenge is to pass to market because of regulations but also because people have an intrinsic belief you can trust a doctor, but will they trust a machine?" he adds.

Law, he says, is the next industry ripe for change. In June, he became chairman of Hong Kong's Dragon Law. The dynamic start-up is credited with helping overhaul the legal industry by making it more accessible and affordable.

For many the idea of mass AI-caused redundancy is terrifying, but Blondeau is pragmatic: humans simply need to rethink careers and education.

"The era where you exit the education system at 16, 21, or 24 and that is it, is broadly gone," he explains.

"People will have to retrain and change skillsets as the technology evolves."

Blondeau disagrees that having a world so catered to your whims and wants might lead to a myopic life, a magnified version of the current social media echo chamber, arguing that it is possible to inject 'serendipity' into the technology, to throw up surprises.

While computers have surpassed humans at specific tasks and games such as chess or Go, predictions of a time when they develop artificial general intelligence (AGI) enabling them to perform any intellectual task an adult can range from as early as 2030 to the end of the century.

Blondeau, who was chief executive at tech firm Dejima when it worked on CALO—one of the biggest AI projects in US history—and developed a precursor to Siri, is more circumspect.

"We will get to some kind of AGI, but its not a given that we will create something that could match our intuition," muses Blondeau, who was also a chief operating officer at Zi Corporation, a leader in predictive text.

"AI might make a better trader, maybe a better customer operative, but will it make a better husband? That machine will need to look at a lot of cases to develop its own intuition. That will take a long time," he says.

The prospect of AI surpassing human capabilities has divided leaders in science and technology.

Microsoft's Bill Gates, British physicist Stephen Hawking and maverick entrepreneur Elon Musk have all sounded the alarm warning unchecked AI could lead to the destruction of mankind.

Yet Blondeau seems unflinchingly positive, pointing out nuclear technology too could have spelled armageddon.

He explains: "Like any invention it can be used for good and bad. So we have to safeguard in each industry. There will be checks along the way, we are not going to wake up one day and suddenly realise the machines are aware." [26]

Artificial intelligence and the coming health revolution

Artificial intelligence can improve health care by analyzing data from apps, smartphones and wearable technology.

Your next doctor could very well be a bot. And bots, or automated programs, are likely to play a key role in finding cures for some of the most difficult-to-treat diseases and conditions.

Artificial intelligence is rapidly moving into health care, led by some of the biggest technology companies and emerging startups using it to diagnose and respond to a raft of conditions.

Consider these examples:

— California researchers detected cardiac arrhythmia with 97 percent accuracy on wearers of an Apple Watch with the AI-based Cariogram application, opening up early treatment options to avert strokes.

— Scientists from Harvard and the University of Vermont developed a machine learning tool—a type of AI that enables computers to learn without being explicitly programmed—to better identify depression by studying Instagram posts, suggesting "new avenues for early screening and detection of mental illness."

— Researchers from Britain's University of Nottingham created an algorithm that predicted heart attacks better than doctors using conventional guidelines.

While technology has always played a role in medical care, a wave of investment from Silicon Valley and a flood of data from connected devices appear to be spurring innovation.

"I think a tipping point was when Apple released its Research Kit," said Forrester Research analyst Kate McCarthy, referring to a program letting Apple users enable data from their daily activities to be used in medical studies.

McCarthy said advances in artificial intelligence has opened up new possibilities for "personalized medicine" adapted to individual genetics.

"We now have an environment where people can weave through clinical research at a speed you could never do before," she said.

Some the same artificial intelligence techniques used in the Google DeepMind Challenge to defeat a grandmaster in the board game

Some the same artificial intelligence techniques used in the Google DeepMind Challenge to defeat a grandmaster in the board game Go can be adapted for medical uses

Predictive analytics

AI is better known in the tech field for uses such as autonomous driving, or defeating experts in the board game Go.

But it can also be used to glean new insights from existing data such as electronic health records and lab tests, says Narges Razavian, a professor at New York University's Langone School of Medicine who led a research project on predictive analytics for more than 100 medical conditions.

"Our work is looking at trends and trying to predict (disease) six months into the future, to be able to act before things get worse," Razavian said.

— NYU researchers analyzed medical and lab records to accurately predict the onset of dozens of diseases and conditions including type 2 diabetes, heart or kidney failure and stroke. The project developed software now used at NYU which may be deployed at other medical facilities.

— Google's DeepMind division is using artificial intelligence to help doctors analyze tissue samples to determine the likelihood that breast and other cancers will spread, and develop the best radiotherapy treatments.

— Microsoft, Intel and other tech giants are also working with researchers to sort through data with AI to better understand and treat lung, breast and other types of cancer.

— Google parent Alphabet's life sciences unit Verily has joined Apple in releasing a smartwatch for studies including one to identify patterns in the progression of Parkinson's disease. Amazon meanwhile offers medical advice through applications on its voice-activated artificial assistant Alexa.

IBM has been focusing on these issues with its Watson Health unit, which uses "cognitive computing" to help understand cancer and other diseases.

When IBM's Watson computing system won the TV game show Jeopardy in 2011, "there were a lot of folks in health care who said that is the same process doctors use when they try to understand health care," said Anil Jain, chief medical officer of Watson Health.

Watson Health, whose Cambridge, Massachusetts office is shown in this photo, is also part of the artificial intelligence health

Watson Health, whose Cambridge, Massachusetts office is shown in this photo, is also part of the artificial intelligence health movement

Systems like Watson, he said, "are able to connect all the disparate pieces of information" from medical journals and other sources "in a much more accelerated way."

"Cognitive computing may not find a cure on day one, but it can help understand people's behavior and habits" and their impact on disease, Jain said.

It's not just major tech companies moving into health.

Research firm CB Insights this year identified 106 digital health startups applying machine learning and predictive analytics "to reduce drug discovery times, provide virtual assistance to patients, and diagnose ailments by processing medical images."

Maryland-based startup Insilico Medicine uses so-called "deep learning" to shorten drug testing and approval times, down from the current 10 to 15 years.

"We can take 10,000 compounds and narrow that down to 10 to find the most promising ones," said Insilico's Qingsong Zhu.

Insilico is working on drugs for amyotrophic lateral sclerosis (ALS), cancer and age-related diseases, aiming to develop personalized treatments.

Finding depression

Artificial intelligence is also increasingly seen as a means for detecting depression and other mental illnesses, by spotting patterns that may not be obvious, even to professionals.

A research paper by Florida State University's Jessica Ribeiro found it can predict with 80 to 90 percent accuracy whether someone will attempt suicide as far off as two years into the future.

IBM is using its Watson supercomputer, seen in this file picture, as part of a broad effort to help medical research and health care through its Watson Health division

Facebook uses AI as part of a test project to prevent suicides by analyzing social network posts.

And San Francisco's Woebot Labs this month debuted on Facebook Messenger what it dubs the first chatbot offering "cognitive behavioral therapy" online—partly as a way to reach people wary of the social stigma of seeking mental health care.

New technologies are also offering hope for rare diseases.

Boston-based startup FDNA uses facial recognition technology matched against a database associated with over 8,000 rare diseases and genetic disorders, sharing data and insights with medical centers in 129 countries via its Face2Gene application.

Cautious optimism

Lynda Chin, vice chancellor and chief innovation officer at the University of Texas System, said she sees "a lot of excitement around these tools" but that technology alone is unlikely to translate into wide-scale health benefits.

One problem, Chin said, is that data from sources as disparate as medical records and Fitbits is difficult to access due to privacy and other regulations.

More important, she said, is integrating data in health care delivery where doctors may be unaware of what's available or how to use new tools.

"Just having the analytics and data get you to step one," said Chin. "It's not just about putting an app on the app store." [25]

Computers are starting to reason like humans

How many parks are near the new home you're thinking of buying? What's the best dinner-wine pairing at a restaurant? These everyday questions require relational reasoning, an important component of higher thought that has been difficult for artificial intelligence (AI) to master. Now, researchers at Google's DeepMind have developed a simple algorithm to handle such reasoning—and it has already beaten humans at a complex image comprehension test.

Humans are generally pretty good at relational reasoning, a kind of thinking that uses logic to connect and compare places, sequences, and other entities. But the two main types of AI—statistical and symbolic—have been slow to develop similar capacities. Statistical AI, or machine learning, is great at pattern recognition, but not at using logic. And symbolic AI can reason about relationships using predetermined rules, but it's not great at learning on the fly.

The new study proposes a way to bridge the gap: an artificial neural network for relational reasoning. Similar to the way neurons are connected in the brain, neural nets stitch together tiny programs that collaboratively find patterns in data. They can have specialized architectures for processing images, parsing language, or even learning games. In this case, the new “relation network” is wired to compare every pair of objects in a scenario individually. “We’re explicitly forcing the network to discover the relationships that exist between the objects,” says Timothy Lillicrap, a computer scientist at He and his team challenged their relation network with several tasks. The first was to answer questions about relationships between objects in a single image, such as cubes, balls, and cylinders. For example: “There is an object in front of the blue thing; does it have the same shape as the tiny cyan thing that is to the right of the gray metal ball?” For this task, the relation network was combined with two other types of neural nets: one for recognizing objects in the image, and one for interpreting the question. Over many images and questions, other machinelearning algorithms were right 42% to 77% of the time. Humans scored a respectable 92%. The new relation network combo was correct 96% of the time, a superhuman score, the researchers report in a paper posted last week on the preprint server arXiv.

The DeepMind team also tried its neural net on a language-based task, in which it received sets of statements such as, “Sandra picked up the football” and “Sandra went to the office.” These were followed by questions like: “Where is the football?” (the office). It performed about as well as its competing AI algorithms on most types of questions, but it really shined on so-called inference questions: “Lily is a Swan. Lily is white. Greg is a swan. What color is Greg?” (white). On those questions, the relation network scored 98%, whereas its competitors each scored about 45%. Finally, the algorithm analyzed animations in which 10 balls bounced around, some connected by invisible springs or rods. Using the patterns of motion alone, it was able to identify more than 90% of the connections. It then used the same training to identify human forms represented by nothing more than moving dots.

“One of the strengths of their approach is that it’s conceptually quite simple,” says Kate Saenko, a computer scientist at Boston University who was not involved in the new work but has also just codeveloped an algorithm that can answer complex questions about images. That simplicity—Lillicrap says most of the advance is captured in a single equation—allows it to be combined with other networks, as it was in the object comparison task. The paper calls it “a simple plug-and-play module” that allows other parts of the system to focus on what they’re good at.

“I was pretty impressed by the results,” says Justin Johnson, a computer scientist at Stanford University in Palo Alto, California, who co-developed the object comparison task-—and also codeveloped an algorithm that does well on it. Saenko adds that a relation network could one day help study social networks, analyze surveillance footage, or guide autonomous cars through traffic.

To approach humanlike flexibility, though, it will have to learn to answer more challenging questions, Johnson says. Doing so might require comparing not just pairs of things, but triplets, pairs of pairs, or only some pairs in a larger set (for efficiency). “I’m interested in moving toward models that come up with their own strategy,” he says. “DeepMind is modeling a particular type of reasoning and not really going after more general relational reasoning. But it is still a superimportant step in the right direction.” [24]

Robot uses deep learning and big data to write and play its own music

A marimba-playing robot with four arms and eight sticks is writing and playing its own compositions in a lab at the Georgia Institute of Technology. The pieces are generated using artificial intelligence and deep learning.

Researchers fed the robot nearly 5,000 complete songs—from Beethoven to the Beatles to Lady Gaga to Miles Davis—and more than 2 million motifs, riffs and licks of music. Aside from giving the machine a seed, or the first four measures to use as a starting point, no humans are involved in either the composition or the performance of the music.

Ph.D. student Mason Bretan is the man behind the machine. He's worked with Shimon for seven years, enabling it to "listen" to music played by humans and improvise over pre-composed chord progressions. Now Shimon is a solo composer for the first time, generating the melody and harmonic structure on its own.

"Once Shimon learns the four measures we provide, it creates its own sequence of concepts and composes its own piece," said Bretan, who will receive his doctorate in music technology this summer at Georgia Tech. "Shimon's compositions represent how music sounds and looks when a robot uses deep neural networks to learn everything it knows about music from millions of humanmade segments."

Shimon has created two songs, using a database of nearly 5,000 songs, including works from Beethoven, Miles Davis and Lady Gaga. This is song two. Credit: Georgia Institute of Technology

Bretan says this is the first time a robot has used deep learning to create music. And unlike its days of improvising, when it played monophonically, Shimon is able to play harmonies and chords. It's also thinking much more like a human musician, focusing less on the next note, as it did before, and more on the overall structure of the composition.

"When we play or listen to music, we don't think about the next note and only that next note," said Bretan. "An artist has a bigger idea of what he or she is trying to achieve within the next few measures or later in the piece. Shimon is now coming up with higher-level musical semantics. Rather than thinking note by note, it has a larger idea of what it wants to play as a whole."

Shimon was created by Bretan's advisor, Gil Weinberg, director of Georgia Tech's Center for Music Technology.

Mason Bretan, a Ph.D. candidate in music technology, is the brain behind Shimon, a marimbaplaying robot that is writing and playing its own music using deep learning. Credit: Georgia Institute of Technology

"This is a leap in Shimon's musical quality because it's using deep learning to create a more structured and coherent composition," said Weinberg, a professor in the School of Music. "We want to explore whether robots could become musically creative and generate new music that we humans could find beautiful, inspiring and strange."

Shimon will create more pieces in the future. As long as the researchers feed it a different seed, the robot will produce something different each time—music that the researchers can't predict. In the first piece, Bretan fed Shimon a melody comprised of eighth notes. It received a sixteenth note melody the second time, which influenced it to generate faster note sequences.

Bretan acknowledges that he can't pick out individual songs that Shimon is referencing. He is able to recognize classical chord progression and influences of artists, such as Mozart, for example.

"They sound like a fusion of jazz and classical," said Bretan, who plays the keyboards and guitar in his free time. "I definitely hear more classical, especially in the harmony. But then I hear chromatic moving steps in the first piece—that's definitely something you hear in jazz." [23]

Learning with light: New system allows optical 'deep learning'

"Deep Learning" computer systems, based on artificial neural networks that mimic the way the brain learns from an accumulation of examples, have become a hot topic in computer science. In addition to enabling technologies such as face- and voice-recognition software, these systems could scour vast amounts of medical data to find patterns that could be useful diagnostically, or scan chemical formulas for possible new pharmaceuticals.

But the computations these systems must carry out are highly complex and demanding, even for the most powerful computers.

Now, a team of researchers at MIT and elsewhere has developed a new approach to such computations, using light instead of electricity, which they say could vastly improve the speed and efficiency of certain deep learning computations. Their results appear today in the journal Nature Photonics in a paper by MIT postdoc Yichen Shen, graduate student Nicholas Harris, professors Marin Soljacic and Dirk Englund, and eight others.

Soljacic says that many researchers over the years have made claims about optics-based computers, but that "people dramatically over-promised, and it backfired." While many proposed uses of such photonic computers turned out not to be practical, a light-based neural-network system developed by this team "may be applicable for deep-learning for some applications," he says.

Traditional computer architectures are not very efficient when it comes to the kinds of calculations needed for certain important neural-network tasks. Such tasks typically involve repeated multiplications of matrices, which can be very computationally intensive in conventional CPU or GPU chips.

After years of research, the MIT team has come up with a way of performing these operations optically instead. "This chip, once you tune it, can carry out matrix multiplication with, in principle, zero energy, almost instantly," Soljacic says. "We've demonstrated the crucial building blocks but not yet the full system."

By way of analogy, Soljacic points out that even an ordinary eyeglass lens carries out a complex calculation (the so-called Fourier transform) on the light waves that pass through it. The way light beams carry out computations in the new photonic chips is far more general but has a similar underlying principle. The new approach uses multiple light beams directed in such a way that their waves interact with each other, producing interference patterns that convey the result of the intended operation. The resulting device is something the researchers call a programmable nanophotonic processor.

The result, Shen says, is that the optical chips using this architecture could, in principle, carry out calculations performed in typical artificial intelligence algorithms much faster and using less than one-thousandth as much energy per operation as conventional electronic chips. "The natural advantage of using light to do matrix multiplication plays a big part in the speed up and power savings, because dense matrix multiplications are the most power hungry and time consuming part in AI algorithms" he says.

The new programmable nanophotonic processor, which was developed in the Englund lab by Harris and collaborators, uses an array of waveguides that are interconnected in a way that can be modified as needed, programming that set of beams for a specific computation. "You can program in any matrix operation," Harris says. The processor guides light through a series of coupled photonic waveguides. The team's full proposal calls for interleaved layers of devices that apply an operation called a nonlinear activation function, in analogy with the operation of neurons in the brain.

To demonstrate the concept, the team set the programmable nanophotonic processor to implement a neural network that recognizes four basic vowel sounds. Even with this rudimentary system, they were able to achieve a 77 percent accuracy level, compared to about 90 percent for conventional systems. There are "no substantial obstacles" to scaling up the system for greater accuracy, Soljacic says.

Englund adds that the programmable nanophotonic processor could have other applications as well, including signal processing for data transmission. "High-speed analog signal processing is something this could manage" faster than other approaches that first convert the signal to digital form, since light is an inherently analog medium. "This approach could do processing directly in the analog domain," he says.

The team says it will still take a lot more effort and time to make this system useful; however, once the system is scaled up and fully functioning, it can find many user cases, such as data centers or security systems. The system could also be a boon for self-driving cars or drones, says Harris, or "whenever you need to do a lot of computation but you don't have a lot of power or time." [22]

Physicists uncover similarities between classical and quantum machine learning

Physicists have found that the structure of certain types of quantum learning algorithms is very similar to their classical counterparts—a finding that will help scientists further develop the quantum versions. Classical machine learning algorithms are currently used for performing complex computational tasks, such as pattern recognition or classification in large amounts of data, and constitute a crucial part of many modern technologies. The aim of quantum learning algorithms is to bring these features into scenarios where information is in a fully quantum form.

The scientists, Alex Monràs at the Autonomous University of Barcelona, Spain; Gael Sentís at the

University of the Basque Country, Spain, and the University of Siegen, Germany; and Peter Wittek at ICFO-The Institute of Photonic Science, Spain, and the University of Borås, Sweden, have published a paper on their results in a recent issue of Physical Review Letters.

"Our work unveils the structure of a general class of quantum learning algorithms at a very fundamental level," Sentís told Phys.org. "It shows that the potentially very complex operations involved in an optimal quantum setup can be dropped in favor of a much simpler operational scheme, which is analogous to the one used in classical algorithms, and no performance is lost in the process. This finding helps in establishing the ultimate capabilities of quantum learning algorithms, and opens the door to applying key results in statistical learning to quantum scenarios."

In their study, the physicists focused on a specific type of machine learning called inductive supervised learning. Here, the algorithm is given training instances from which it extracts general rules, and then applies these rules to a variety of test (or problem) instances, which are the actual problems that the algorithm is trained for. The scientists showed that both classical and quantum inductive supervised learning algorithms must have these two phases (a training phase and a test phase) that are completely distinct and independent. While in the classical setup this result follows trivially from the nature of classical information, the physicists showed that in the quantum case it is a consequence of the quantum no-cloning theorem—a theorem that prohibits making a perfect copy of a quantum state.

By revealing this similarity, the new results generalize some key ideas in classical statistical learning theory to quantum scenarios. Essentially, this generalization reduces complex protocols to simpler ones without losing performance, making it easier to develop and implement them. For instance, one potential benefit is the ability to access the state of the learning algorithm in between the training and test phases. Building on these results, the researchers expect that future work could lead to a fully quantum theory of risk bounds in quantum statistical learning.

"Inductive supervised quantum learning algorithms will be used to classify information stored in quantum systems in an automated and adaptable way, once trained with sample systems," Sentís said. "They will be potentially useful in all sorts of situations where information is naturally found in a quantum form, and will likely be a part of future quantum information processing protocols. Our results will help in designing and benchmarking these algorithms against the best achievable performance allowed by quantum mechanics." [21]

Artificial Intelligence's Potential Will Be Realized by Quantum Computing

Over the last decade, advances in computing have given us a teaser of what artificial intelligence is capable of. Through machine learning, algorithms can learn on their own using large amounts of real-time data. These algorithms can answer myriad questions, including what we should buy, what we should watch, and who we should date. However, the true benefits of AI and machine learning are yet to be discovered, and they extend to more impactful application areas such as computer vision, speech recognition, and medicine.

Artificial intelligence is a mammoth computing challenge because of the large amount of new data generated every day. Cisco forecasts that by the year 2020, annual global data center traffic will reach 1.3 zettabytes (1 trillion gigabytes) per month, and Gartner estimates the number of connected devices in the world will be more than 20 million by then. At this year's IEEE International Solid-State Circuits Conference, it became clear that quantum computing will make it possible to process exponentially increasing amounts of data necessary for machine-learning applications.

SAY HELLO TO QUANTUM COMPUTING

Quantum computing has long been referred to as the "sleeping giant" of computing. It has the potential to tackle large mathematical problems beyond the reach of supercomputers, but its scalability remains limited by the extreme cooling required to keep quantum bits (qubits) stable and the bulky equipment required to read and write quantum data.

What is quantum computing, and why is it so fast? In contrast to classical binary data, which can be only a 0 or a 1 at any one time, a quantum state can be both a 0 and a 1 at the same time. That enables exponentially faster computation using specialized hardware, leading to faster analytics and predictions, which could enable advances in cybersecurity, surveillance, fraud detection, legal research, and early disease detection.

Quantum computing cannot arrive fast enough. As big data and the Internet of Things continue to proliferate, the amount of data collected is exceeding the rate at which we can process it. Semiconductor chips for high-speed machine learning are a step in the right direction, but the true realization of AI will happen only after we solve some of the basic problems with quantum computing.

FACE THE FACTS

The first, and probably most challenging, problem is cooling qubits down to cryogenic temperatures (below minus 150 °C) to preserve quantum states. Second, new algorithms must be developed that specifically target quantum hardware. IBM recently released a free platform, the Quantum Experience, that allows anyone to connect to the company's quantum processor to experiment with algorithms and learn how to manipulate quantum data. Such open projects are a step toward building a community that will understand how to apply AI algorithms to quantum computers, once they do become available.

The third challenge is building and integrating enough qubits to be able to solve meaningful problems. Researchers at the QuTech research center in Delft, Netherlands, are working on this grand challenge with interdisciplinary teams as well as industry partners such as Intel and Microsoft. Today D-Wave of Vancouver, B.C., Canada, is the only company selling quantum computers. The company's recent announcement of a 2,000-qubit machine for defense and intelligence applications shows promise that ubiquitous quantum computing is not too far away.

WILL QUANTUM COMPUTERS KEEP US SAFE?

Once quantum computers know everything about us and can predict our next moves, what happens then? Will we be safe? Will our data be protected? There are many unanswered ethical and technical questions, but luckily researchers have kept up.

Security and cryptography for the quantum world have been hot areas of research for the past 25 years. Technologies such as quantum key distribution will provide us with a means to communicate securely, while post-quantum cryptography will ensure that our encrypted data remains safe, even during brute-force attacks by a quantum computer.

The IEEE Rebooting Computing Initiative has an important role to play in the development of nextgeneration computing paradigms, which span across multiple technical areas including circuits and systems, components and devices, and electronic design automation.

Human life expectancy continues to rise, and quantum computing–based technologies undoubtedly will help us solve some pressing challenges in the coming decades. However, we must ensure that the energy consumption of quantum-based technologies remains feasible and within the confines of the planet’s natural resources.

Public policy groups such as IEEE-USA should continue to work with governments to ensure adequate funding for science and engineering jobs and research, while simultaneously expressing concerns about the importance of energy regulations. We should remain optimistic that quantum computing and AI will continue to improve our lives, but we also should continue to hold companies, organizations, and governments accountable for how our private data is used, as well as the technology’s impact on the environment. [20]

Ready, Set, Go! Rematch of man vs machine in ancient game

It's man vs machine this week as Google's artificial intelligence programme AlphaGo faces the world's top-ranked Go player in a contest expected to end in another victory for rapid advances in AI.

China's 19-year-old Ke Jie is given little chance in the three-game series beginning Tuesday in the eastern Chinese city of Wuzhen after AlphaGo stunned observers last year by trouncing South Korean grandmaster Lee Se-Dol four games to one.

Lee's loss in Seoul marked the first time a computer programme had beaten a top player in a full match in the 3,000-year-old Chinese board game, and has been hailed as a landmark event in the development of AI.

AI has previously beaten humans in cerebral contests, starting with IBM's Deep Blue defeating chess grandmaster Garry Kasparov in 1997, but AlphaGo's win last year is considered the most significant win for AI yet.

Go is considered perhaps the most complex game ever devised, with an incomputable number of move options that puts a premium on "intuition."

Proponents had considered it a bastion in which human thought would remain superior, at least for the foreseeable future.

AlphaGo's triumph fuelled hopes of a brave new world in which AI is applied not only to driverless cars or "smart homes", but to helping mankind figure out some of the most complex scientific, technical, and medical problems.

"AlphaGo's successes hint at the possibility for general AI to be applied to a wide range of tasks and areas, to perhaps find solutions to problems that we as human experts may not have considered," Demis Hassabis, founder of London-based DeepMind, which developed AlphaGo, said ahead of this week's matches.

AI's ultimate goal is to create "general" or multi-purpose, rather than "narrow," task-specific intelligence—something resembling human reasoning and the ability to learn.

Sci-fi nightmare?

But for some, it conjures sci-fi images of a future in which machines "wake up" and enslave humanity.

Physicist Stephen Hawking is a leading voice for caution, warning in 2015 that computers may outsmart humans, "potentially subduing us with weapons we cannot even understand."

Ke faces AlphaGo on Tuesday, Thursday and Saturday.

Ke is a brash prodigy who went pro at 11 years old, has been world number one for more than two years, and has described himself as a "pretentious prick".

After AlphaGo flattened Lee, Ke declared he would never lose to the machine.

"Bring it on," he said on China's Twitter-like Weibo.

But he has tempered his bravado since then.

Ke was among many top Chinese players who were trounced in online contests in January by a mysterious adversary who reportedly won 60 straight victories.

That opponent—cheekily calling itself "The Master"—was later revealed by DeepMind to have been an updated AlphaGo.

"Even that was not AlphaGo's best performance," Gu Li, a past national champion, told Chinese state media last week.

"It would be very hard for Ke to play against it, but then again, Ke has also been working extremely hard to change his methods in preparation. I hope he can play well."

Go involves two players alternately laying black and white stones on a grid. The winner is the player who seals off the most territory.

AlphaGo uses two sets of "deep neural networks" containing millions of connections similar to neurons in the brain.

It is partly self-taught—having played millions of games against itself after initial programming. [19]

Google unveils latest tech tricks as computers get smarter

Google's computer programs are gaining a better understanding of the world, and now it wants them to handle more of the decision-making for the billions of people who use its services.

CEO Sundar Pichai and other top executives brought Google's audacious ambition into sharper focus Wednesday at an annual conference attended by more than 7,000 developers who design apps to work with its wide array of digital services.

Among other things, Google unveiled new ways for its massive network of computers to identify images, as well as recommend, share, and organize photos. It also is launching an attempt to make its voice-controlled digital assistant more proactive and visual while expanding its audience to Apple's iPhone, where it will try to outwit an older peer, Siri.

The push marks another step toward infusing nearly all of Google's products with some semblance of artificial intelligence—the concept of writing software that enables computers to gradually learn to think more like humans.

Google punctuated the theme near the end of the conference's keynote address by projecting the phrase, "Computing that works like we do."

Pichai has made AI the foundation of his strategy since becoming Google's CEO in late 2015, emphasizing that technology is rapidly evolving from a "mobile-first" world, where smartphones steer the services that companies are building, to an "AI-first" world, where the computers supplement the users' brains.

AI unnerves many people because it conjures images of computers eventually becoming smarter than humans and eventually running the world. That may sound like science fiction, but the threat is real enough to prompt warnings from respected technology leaders and scientists, including Tesla Motors CEO Elon Musk and Stephen Hawking.

But Pichai and Google co-founder Larry Page, now CEO of Google corporate parent Alphabet Inc., see it differently. They believe computers can take over more of the tedious, grunt work so humans have more time to think about deeper things and enjoy their lives with friends and family.

Other big tech companies, including Amazon.com, Microsoft, Apple and Facebook, also are making AI a top priority as they work on similar services to help users stay informed and manage their lives.

Google believes it can lead the way in AI largely because it has built a gigantic network of data centers with billions of computers scattered around the world. This while people using its dominant internet search engine and leading email service have been feeding the machines valuable pieces of personal information for nearly 20 years.

Now, Google is drawing upon that treasure trove to teach new tricks to its digital assistant, which debuted last year on its Pixel phone and an internet-connected speaker called Home that is trying to mount a challenge to Amazon's Echo. Google Assistant is on more than 100 million devices after being on the market for slightly more than six months and now is trying to invade new territory with a free app released Wednesday that works on the operating system powering Apple's iPhone. Previously, the assistant worked only on Google's Android software.

Google's assistant will be at a disadvantage on the iPhone, though, because Siri—a concierge that Apple introduced in 2011—is built into that device.

A new service called Google Lens will give Assistant a new power. Lens uses AI to identify images viewed through a phone. For instance, point the phone at a flower and Assistant will call upon Lens to identify the type of flower. Or point the camera at the exterior of a restaurant and it will pull up reviews of the place.

Pinterest has a similar tool. Also called Lens, it lets people point their cameras at real-world items and find out where to buy them, or find similar things online.

Google Photos is adding a new tool that will prompt you to share photos you take of people you know. For instance, Photos will notice when you take a shot of a friend and nudge you to send it to her, so you don't forget. Google will also let you share whole photo libraries with others. Facebook has its own version of this feature in its Moments app.

One potentially unsettling new feature in Photos will let you automatically share some or all of your photos with other people. Google maintains the feature will be smart enough so that you would auto-share only specific photos—say, of your kids—to your partner or a friend.

Google is also adding a feature to Photos to create soft-cover and hard-cover albums of pictures at prices beginning at $9.99. The app will draw upon its AI powers to automatically pick out the best pictures to put in the album. [18]

Microsoft aims to make artificial intelligence mainstream

Microsoft on Wednesday unveiled new tools intended to democratize artificial intelligence by enabling machine smarts to be built into software from smartphone games to factory floors.

The US technology titan opened its annual Build Conference by highlighting programs with artificial intelligence that could tap into services in the internet "cloud" and even take advantage of computing power in nearby machines.

"We are infusing AI into every product and service we offer," said Microsoft executive vice president of artificial intelligence and research Harry Shum.

"We've been creating the building blocks for the current wave of AI breakthroughs for more than two decades."

Microsoft research has gone deep into areas such as machine learning, speech recognition, and enabling machines to recognize what they "see."

"Now, we're in the unique position of being able to use those decades of research breakthroughs," Shum said.

Microsoft rivals including Amazon, Apple, Google and IBM have all been aggressively pursing the promise and potential of artificial intelligence.

Artificial intelligence is getting a foothold in people's homes, with personal assistants answering questions and controlling connected devices such as appliances or light bulbs.

Digital assistants already boast features such as reminding people of appointments entered into calendars and chiming in with advice to set out early if traffic is challenging.

Steering away from '1984'

Microsoft chief executive Satya Nadella, who opened the Seattle conference, also highlighted the need to build trust in technology, saying new applications must avoid the dystopian futures feared by some.

Nadella's presentation included images from George Orwell's "1984" and Aldous Huxley's "Brave New World" to underscore the issue of responsibility of those creating new technologies.

"What Orwell prophesied in '1984,' where technology was being used to monitor, control, dictate, or what Huxley imagined we may do just by distracting ourselves without any meaning or purpose," Nadella said.

"Neither of these futures is something that we want... The future of computing is going to be defined by the choices that you as developers make and the impact of those choices on the world."

Microsoft's aim on Wednesday was on businesses and software developers, whether they be students building a fun app or professional technology teams.

"Microsoft is trying to use AI for businesses to solve business problems and app developers to make applications better," said Moor Insights and Strategy principal analyst Patrick Moorhead.

"Which is different from Amazon, Facebook, and Google whose primary business model is to mine personal information using AI to sell you things or put ads in front of you."

Microsoft is taking a unique approach by letting developers customize gesture commands, voice recognition and more instead of making them conform to settings in "off-the-shelf" AI, according to the analyst.

Microsoft executives used demonstrations to provide a glimpse into a near future in which artificial intelligence hosted online works with internet linked devices such as construction site cameras to alert workers of dangers, available tools, or unauthorized activities.

Devices like smart surveillance cameras, smartphones, or factory floor machines were referred to as "edge computing," with the coordination of cloud power and intelligent edge devices improving productivity and safety on the ground.

Windows numbers rise

Nadella also told developers that some 500 million devices now run on Microsoft's latest Windows 10 operating system, creating a huge audience for their software creations.

Microsoft's online Office 365 service has some 100 million commercial users monthly, while Cortana digital assistant is used by 140 people monthly, according to the Redmond, Washington-based technology firm.

"The future is a smart cloud," Nadella said, forecasting a future in which mobile devices take back seats to digital assistants hosted in the cloud that follow people from device to device.

"It is a pretty amazing world you can create using intelligent cloud and intelligent edge." [17]

Google Brain posse takes neural network approach to translation

The closer we can get a machine translation to be on par with expert human translation, the happier lots of people struggling with translations will be.

Work done at Google Brain is drawing interest among those watching for signs of progress in machine translation.

New Scientist said, "Google's latest take on machine translation could make it easier for people to communicate with those speaking a different language, by translating speech directly into text in a language they understand."

Machine translation of speech normally works by converting it to text, then translating that into text in another language. Any error in speech recognition will lead to an error in transcription and a mistake in the translation, the report added.

The Google Brain team cut out the middle step. "By skipping transcription, the approach could potentially allow for more accurate and quicker translations."

The researchers have authored a paper, Sequence-to-Sequence Models Can Directly Transcribe Foreign Speech" and it is on arXiv. Authors are Ron Weiss, Jan Chorowski, Navdeep Jaitly, Yonghui Wu and Zhifeng Chen.

The authors in their paper described their approach involving an encoder-decoder deep neural network architecture that directly translates speech in one language into text in another.

"We present a model that directly translates speech into text in a different language. One of its striking characteristics is that its architecture is essentially the same as that of an attention-based ASR neural system." ASR stands for automatic speech recognition.

What did the authors do for testing? Matt Reynolds in New Scientist: "The team trained its system on hundreds of hours of Spanish audio with corresponding English text. In each case, it used several layers of neural networks – computer systems loosely modelled on the human brain – to match sections of the spoken Spanish with the written translation."

Reynolds said they analyzed the waveform of the Spanish audio to learn which parts seemed to correspond with which chunks of written English.

"When it was then asked to translate, each neural layer used this knowledge to manipulate the audio waveform until it was turned into the corresponding section of written English."

Results? The team reported 'state-of-the-art performance' on the conversational Spanish to English speech translation tasks, said The Stack.

The model could outperform cascades of speech recognition and machine translation technologies.

The team used the BLEU score, which judges machine translations based on how close they are to that by a professional human. BLEU stands for bilingual evaluation understudy. According to Slator, "BLEU has become the de facto standard in evaluating machine translation output."

Using BLEU, the proposed system recorded 1.8 points over other translation models, said The Stack. "It learns to find patterns of correspondence between the waveforms in the source language and the written text," said Dzmitry Bahdanau at the University of Montreal in Canada (who wasn't involved with the work), quoted in New Scientist.

Moving forward, the authors in their paper wrote that "An interesting extension would be to construct a multilingual speech translation system following in which a single decoder is shared across multiple languages, passing a discrete input token into the network to select the desired output language."

In other words, as Reynolds said in New Scientist, "The Google Brain researchers suggest the new speech-to-text approach may also be able to produce a system that can translate multiple languages." [16]

A new open source dataset links human motion and language

Researchers have created a large, open source database to support the development of robot activities based on natural language input. The new KIT Motion-Language Dataset will help to unify and standardize research linking human motion and natural language, as presented in an article in Big Data.

In the article "The KIT Motion-Language Dataset," Matthias Plappert, Christian Mandery, and Tamim Asfour, Institute for Anthropomatics and Robotics, Karlsruhe Institute of Technology (KIT), Germany, describe a novel crowd-sourcing approach and purpose-built web-based tool they used to develop their publicly available dataset that annotates motions. Their approach relies on a unified representation that is independent of the capture system or marker set to be able to merge data from different existing motion capture databases into the KIT Motion-Language Dataset. It currently includes about 4,000 motions and more than 6,200 annotations in natural language that contain nearly 53,000 words.

The article is part of a special issue of Big Data on "Big Data in Robotics" led by Guest Editors Jeannette Bohg, PhD, Matei Ciocarlie, PhD, Jaview Civera, PhD, and Lydia Kavraki, PhD.

"Human motion is complex and nuanced in terms of how it can be described, and it is surprisingly difficult to even retrieve motions from databases corresponding to natural language descriptions. There is a great need to describe robotic systems in natural language that captures the richness associated with motion, but doing this accurately is an extremely challenging problem," says Big Data Editor-in-Chief Vasant Dhar, Professor at the Stern School of Business and the Center for Data Science at New York University. "Plappert and his colleagues do a wonderful job using a novel crowd-sourcing approach and a tool to document the annotation process itself along with methods for obtaining high quality inputs and selecting motions that require further annotation automatically. They have constructed an impressive database of motions and annotations that can serve as a test-bed for research in this area. It is a great service to the research community." [15]

Researchers use artificial neural network to simulate a quantum many-body system

A pair of physicists with ETH Zurich has developed a way to use an artificial neural network to characterize the wave function of a quantum many-body system. In their paper published in the journal Science, Giuseppe Carleo and Matthias Troyer describe how they coaxed a neural network to simulate some aspects of a quantum many-body system. Michael Hush with the University of New South Wales offers a Perspectives piece on the work done by the pair in the same journal issue and also outlines the problems other researchers have faced when attempting to solve the same problem.

One of the difficult challenges facing physicists today is coming up with a way to simulate quantum many-body systems, i.e., showing all the states that exist in a given system, such as a chunk of matter. Such systems grow complicated quickly—a group of just 100 quantum particles, for example, could have as many as 1035 spin states. Even the most powerful modern computers very quickly become overwhelmed trying to depict such systems. In this new effort, the researchers took a different approach—instead of attempting to calculate every possible state, they used a neural network to generalize the entire system.

The pair began by noting that the system used to defeat a Go world champion last year might be modified in a way that could simulate a many-body system. They created a simplified version of the same type of neural network and programed it to simulate the wave function of a multi-body system (by using a set of weights and just one layer of hidden biases). They then followed up by getting the neural network to figure out the ground state of a system. To see how well their system worked, they ran comparisons with problems that have already been solved and report that their system was better than those that rely on a brute-force approach.

The system was a proof-of-concept rather than an actual tool for use by physicists, but it demonstrates what is possible—large efforts, as Hush notes, that involve more hidden biases and weights could result in a tool with groundbreaking applications. [14]

Google DeepMind project taking neural networks to a new level

A team of researchers at Google's DeepMind Technologies has been working on a means to increase the capabilities of computers by combining aspects of data processing and artificial intelligence and have come up with what they are calling a differentiable neural computer (DNC.) In their paper published in the journal Nature, they describe the work they are doing and where they believe it is headed. To make the work more accessible to the public team members, Alexander Graves and Greg Wayne have posted an explanatory page on the DeepMind website.

DeepMind is a Google-owned company that does research on artificial intelligence, including neural networks, and more recently, deep neural networks, which are computer systems that learn how to do things by seeing many other examples. But, as Graves and Wayne note, such systems are typically limited by their ability to use and manipulate memory in useful ways because they are in essence based on decision trees. The work being done with DNCs is meant to overcome that deficiency, allowing for the creation of computer systems that are not only able to learn, but which will be able to remember what they have learned and then to use that information for decision making when faced with a new task. The researchers highlight an example of how such a system might be of greater use to human operators—a DNC could be taught how to get from one point to another, for example, and then caused to remember what it learned along the way. That would allow for the creation of a system that offers the best route to take on the subway, perhaps, or on a grander scale, advice on adding roads to a city.

By adding memory access to neural networking, the researchers are also looking to take advantage of another ability we humans take for granted—forming relationships between memories, particularly as they relate to time. One example would be when a person walks by a candy store and the aroma immediately takes them back to their childhood—to Christmas, perhaps, and the emotions that surround the holiday season. A computer able to make the same sorts of connections would be able to make similar leaps, jumping back to a sequence of connected learning events that could be useful in providing an answer to a problem about a certain topic—such as what caused the Great Depression or how Google became so successful.

The research team has not yet revealed if there are any plans in place for actually using the systems they are developing, but it would seem likely, and it might be gradual, showing up in better search results when using Google, for example. [13]

The Extraordinary Link Between Deep Neural Networks and the Nature of the Universe

Nobody understands why deep neural networks are so good at solving complex problems. Now physicists say the secret is buried in the laws of physics.

In the last couple of years, deep learning techniques have transformed the world of artificial intelligence. One by one, the abilities and techniques that humans once imagined were uniquely our own have begun to fall to the onslaught of ever more powerful machines. Deep neural networks are now better than humans at tasks such as face recognition and object recognition. They've mastered the ancient game of Go and thrashed the best human players.

But there is a problem. There is no mathematical reason why networks arranged in layers should be so good at these challenges. Mathematicians are flummoxed.

Despite the huge success of deep neural networks, nobody is quite sure how they achieve their success.

Today that changes thanks to the work of Henry Lin at Harvard University and Max Tegmark at MIT. These guys say the reason why mathematicians have been so embarrassed is that the answer depends on the nature of the universe. In other words, the answer lies in the regime of physics rather than mathematics.

First, let's set up the problem using the example of classifying a megabit grayscale image to determine whether it shows a cat or a dog.

Such an image consists of a million pixels that can each take one of 256 grayscale values. So in theory, there can be 2561000000 possible images, and for each one it is necessary to compute whether it shows a cat or dog. And yet neural networks, with merely thousands or millions of parameters, somehow manage this classification task with ease.

In the language of mathematics, neural networks work by approximating complex mathematical functions with simpler ones. When it comes to classifying images of cats and dogs, the neural network must implement a function that takes as an input a million grayscale pixels and outputs the probability distribution of what it might represent.

The problem is that there are orders of magnitude more mathematical functions than possible networks to approximate them. And yet deep neural networks somehow get the right answer.

Now Lin and Tegmark say they've worked out why. The answer is that the universe is governed by a tiny subset of all possible functions. In other words, when the laws of physics are written down mathematically, they can all be described by functions that have a remarkable set of simple properties.

So deep neural networks don't have to approximate any possible mathematical function, only a tiny subset of them.

To put this in perspective, consider the order of a polynomial function, which is the size of its highest exponent. So a quadratic equation like y=x2 has order 2, the equation y=x24 has order 24, and so on.

Obviously, the number of orders is infinite and yet only a tiny subset of polynomials appear in the laws of physics. "For reasons that are still not fully understood, our universe can be accurately described by polynomial Hamiltonians of low order," say Lin and Tegmark. Typically, the polynomials that describe laws of physics have orders ranging from 2 to 4.

The laws of physics have other important properties. For example, they are usually symmetrical when it comes to rotation and translation. Rotate a cat or dog through 360 degrees and it looks the same; translate it by 10 meters or 100 meters or a kilometer and it will look the same. That also simplifies the task of approximating the process of cat or dog recognition.

These properties mean that neural networks do not need to approximate an infinitude of possible mathematical functions but only a tiny subset of the simplest ones.

There is another property of the universe that neural networks exploit. This is the hierarchy of its structure. "Elementary particles form atoms which in turn form molecules, cells, organisms, planets, solar systems, galaxies, etc.," say Lin and Tegmark. And complex structures are often formed through a sequence of simpler steps.

This is why the structure of neural networks is important too: the layers in these networks can approximate each step in the causal sequence.

Lin and Tegmark give the example of the cosmic microwave background radiation, the echo of the Big Bang that permeates the universe. In recent years, various spacecraft have mapped this radiation in ever higher resolution. And of course, physicists have puzzled over why these maps take the form they do.

Tegmark and Lin point out that whatever the reason, it is undoubtedly the result of a causal hierarchy. “A set of cosmological parameters (the density of dark matter, etc.) determines the power spectrum of density fluctuations in our universe, which in turn determines the pattern of cosmic microwave background radiation reaching us from our early universe, which gets combined with foreground radio noise from our galaxy to produce the frequency-dependent sky maps that are recorded by a satellite-based telescope,” they say.

Each of these causal layers contains progressively more data. There are only a handful of cosmological parameters but the maps and the noise they contain are made up of billions of numbers. The goal of physics is to analyze the big numbers in a way that reveals the smaller ones.

And when phenomena have this hierarchical structure, neural networks make the process of analyzing it significantly easier.

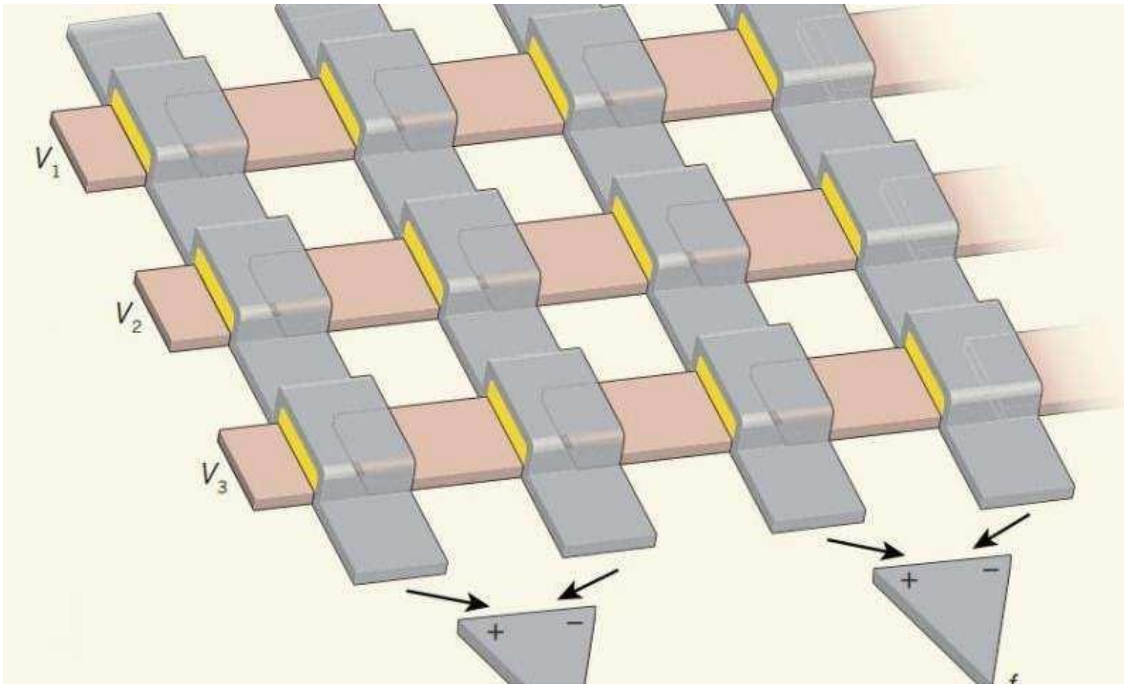
“We have shown that the success of deep and cheap learning depends not only on mathematics but also on physics, which favors certain classes of exceptionally simple probability distributions that deep learning is uniquely suited to model,” conclude Lin and Tegmark.

That’s interesting and important work with significant implications. Artificial neural networks are famously based on biological ones. So not only do Lin and Tegmark’s ideas explain why deep learning machines work so well, they also explain why human brains can make sense of the universe. Evolution has somehow settled on a brain structure that is ideally suited to teasing apart the complexity of the universe.

This work opens the way for significant progress in artificial intelligence. Now that we finally understand why deep neural networks work so well, mathematicians can get to work exploring the specific mathematical properties that allow them to perform so well. “Strengthening the analytic understanding of deep learning may suggest ways of improving it,” say Lin and Tegmark.

Deep learning has taken giant strides in recent years. With this improved understanding, the rate of advancement is bound to accelerate. [12]

Researchers create first neural-network chip built just with memristors



Memristors may sound like something from a sci-fi movie, but they actually exist—they are electronic analog memory devices that are modeled on human neurons and synapses. Human consciousness, some believe, is in reality, nothing more than an advanced form of memory retention and processing, and it is analog, as opposed to computers, which of course are digital. The idea for memristors was first dreamed up by University of California professor Leon Chua back in 1971, but it was not until a team working at Hewlett-Packard in 2008, first built one. Since then, a lot of research has gone into studying the technology, but until now, no one had ever built a neural-network chip based exclusively on them.

Up till now, most neural networks have been software based, Google, Facebook and IBM, for example, are all working on computer systems running such learning networks, mostly meant to pick faces out of a crowd, or return an answer based on a human phrased question. While the gains in such technology have been obvious, the limiting factor is the hardware—as neural networks grow in size and complexity, they begin to tax the abilities of even the fastest computers. The next step, most in the field believe, is to replace transistors with memristors—each on its own is able to learn, in ways similar to the way neurons in the brain learn when presented with something new. Putting them on a chip would of course reduce the overhead needed to run such a network.

The new chip, the team reports, was created using transistor-free metal-oxide memristor crossbars and represents a basic neural network able to perform just one task—to learn and recognize patterns in very simple 3 × 3-pixel black and white images. The experimental chip, they add, is an important step towards the creation of larger neural networks that tap the real power of memristors.

It also makes possible the idea of building computers in lock-step with advances in research looking into discovering just how exactly our neurons work at their most basic level.

Despite much progress in semiconductor integrated circuit technology, the extreme complexity of the human cerebral cortex, with its approximately 1014 synapses, makes the hardware implementation of neuromorphic networks with a comparable number of devices exceptionally challenging. To provide comparable complexity while operating much faster and with manageable power dissipation, networks based on circuits combining complementary metal-oxidesemiconductors (CMOSs) and adjustable two-terminal resistive devices (memristors) have been developed. In such circuits, the usual CMOS stack is augmented with one or several crossbar layers, with memristors at each crosspoint. There have recently been notable improvements in the fabrication of such memristive crossbars and their integration with CMOS circuits, including first demonstrations of their vertical integration. Separately, discrete memristors have been used as artificial synapses in neuromorphic networks. Very recently, such experiments have been extended to crossbar arrays of phase-change memristive devices. The adjustment of such devices, however, requires an additional transistor at each crosspoint, and hence these devices are much harder to scale than metal-oxide memristors, whose nonlinear current–voltage curves enable transistor-free operation. Here we report the experimental implementation of transistor-free metal-oxide memristor crossbars, with device variability sufficiently low to allow operation of integrated neural networks, in a simple network: a single-layer perceptron (an algorithm for linear classification). The network can be taught in situ using a coarse-grain variety of the delta rule algorithm to perform the perfect classification of 3 × 3-pixel black/white images into three classes (representing letters). This demonstration is an important step towards much larger and more complex memristive neuromorphic networks. [11]

Computers that mimic the function of the brain

Concept illustration (stock image). A new step forward in memristor technology could bring us closer to brain-like computing.

Researchers are always searching for improved technologies, but the most efficient computer possible already exists. It can learn and adapt without needing to be programmed or updated. It has nearly limitless memory, is difficult to crash, and works at extremely fast speeds. It's not a Mac or a PC; it's the human brain. And scientists around the world want to mimic its abilities.

Both academic and industrial laboratories are working to develop computers that operate more like the human brain. Instead of operating like a conventional, digital system, these new devices could potentially function more like a network of neurons.

"Computers are very impressive in many ways, but they're not equal to the mind," said Mark Hersam, the Bette and Neison Harris Chair in Teaching Excellence in Northwestern University's McCormick School of Engineering. "Neurons can achieve very complicated computation with very low power consumption compared to a digital computer."

A team of Northwestern researchers, including Hersam, has accomplished a new step forward in electronics that could bring brain-like computing closer to reality. The team's work advances memory resistors, or "memristors," which are resistors in a circuit that "remember" how much current has flowed through them.

The research is described in the April 6 issue of Nature Nanotechnology. Tobin Marks, the Vladimir N. Ipatieff Professor of Catalytic Chemistry, and Lincoln Lauhon, professor of materials science and engineering, are also authors on the paper. Vinod Sangwan, a postdoctoral fellow co-advised by Hersam, Marks, and Lauhon, served as first author. The remaining co-authors--Deep Jariwala, In Soo Kim, and Kan-Sheng Chen--are members of the Hersam, Marks, and/or Lauhon research groups.

"Memristors could be used as a memory element in an integrated circuit or computer," Hersam said. "Unlike other memories that exist today in modern electronics, memristors are stable and remember their state even if you lose power."

Current computers use random access memory (RAM), which moves very quickly as a user works but does not retain unsaved data if power is lost. Flash drives, on the other hand, store information when they are not powered but work much slower. Memristors could provide a memory that is the best of both worlds: fast and reliable. But there's a problem: memristors are two-terminal electronic devices, which can only control one voltage channel. Hersam wanted to transform it into a threeterminal device, allowing it to be used in more complex electronic circuits and systems.

Hersam and his team met this challenge by using single-layer molybdenum disulfide (MoS2), an atomically thin, two-dimensional nanomaterial semiconductor. Much like the way fibers are arranged in wood, atoms are arranged in a certain direction--called "grains"--within a material. The sheet of MoS2 that Hersam used has a well-defined grain boundary, which is the interface where two different grains come together.

"Because the atoms are not in the same orientation, there are unsatisfied chemical bonds at that interface," Hersam explained. "These grain boundaries influence the flow of current, so they can serve as a means of tuning resistance."

When a large electric field is applied, the grain boundary literally moves, causing a change in resistance. By using MoS2 with this grain boundary defect instead of the typical metal-oxide-metal memristor structure, the team presented a novel three-terminal memristive device that is widely tunable with a gate electrode. [10]

Fastest Operating System for Quantum Computing Developed By Researchers

Researchers have been working on significant activities to develop quantum computing technology that might enable the development of a Superfast quantum computer, though there has been less work done in the development of an Operating System that might control the quantum computers.

However, CQCL researchers have done just that and also believe that "Quantum computing will be a reality much earlier than originally anticipated. It will have profound and far-reaching effects on a vast number of aspects of our daily lives."

Polishing Quantum Computing:

CQCL's new operating system for the quantum computer comes just days after IBM researchers brought us even closer to a working Superfast quantum computer by discovering a new method for correcting two errors that a quantum computer can make.

One of the biggest issues that prevent us from developing Superfast Quantum Computers is — Quantum computing is incredibly fragile, and even the slightest fault can cause a major error to the computer.

However, IBM researchers have discovered a new way to detect both types of quantum computer errors, and revealed a new, square quantum bit circuit design that, according to them, can be easily scaled up to make high-performance computers, according to the details published in Nature Communications.

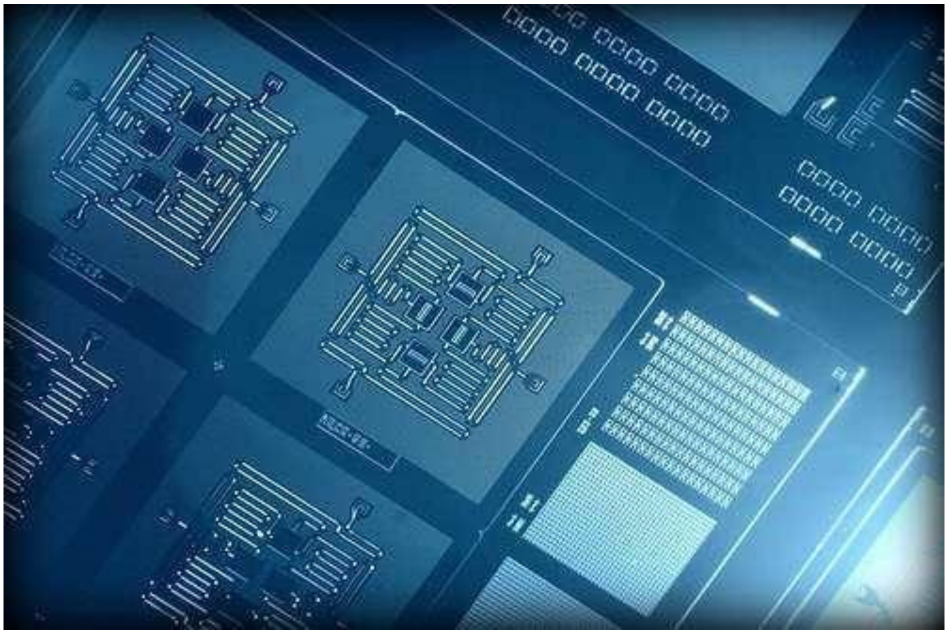
What’s the difference between a Regular computer and a Quantum computer?

Traditional computers use the "bits" to represent information as a 0 or a 1; therefore they are so much slower. On the other hand, Quantum computers use "qubits" (quantum bits) to represent information as a 0, 1, or both at the same time.

But, the major problem with qubits is that they sometimes flip without warning. Qubits can suddenly flip from 0 to 1, which is called a bit flip, or from 0+1 to 0-1, which is called a phase flip. And these flipping are the actual culprits that creates all kinds of errors in a quantum computer.

Until now, scientists could only detect one error at a time. However, IBM's quantum circuit, consisting of four superconducting qubits on a one-quarter inch square chip, allowed researchers to detect bit-flip as well as phase-flip quantum errors simultaneously. [9]

Scientists achieve critical steps to building first practical quantum computer



Layout of IBM's four superconducting quantum bit device. Using a square lattice, IBM is able to detect both types of quantum errors for the first time. This is the best configuration to add more qubits to scale to larger systems.

With Moore's Law expected to run out of steam, quantum computing will be among the inventions that could usher in a new era of innovation across industries.
Quantum computers promise to open up new capabilities in the fields of optimization and simulation simply not possible using today's computers. If a quantum computer could be built with just 50 quantum bits (qubits), no combination of today's TOP500 supercomputers could successfully outperform it.

The IBM breakthroughs, described in the April 29 issue of the journal Nature Communications, show for the first time the ability to detect and measure the two types of quantum errors (bit-flip and phase-flip) that will occur in any real quantum computer. Until now, it was only possible to address one type of quantum error or the other, but never both at the same time. This is a necessary step toward quantum error correction, which is a critical requirement for building a practical and reliable large-scale quantum computer.

IBM's novel and complex quantum bit circuit, based on a square lattice of four superconducting qubits on a chip roughly one-quarter-inch square, enables both types of quantum errors to be detected at the same time. By opting for a square-shaped design versus a linear array – which prevents the detection of both kinds of quantum errors simultaneously – IBM's design shows the best potential to scale by adding more qubits to arrive at a working quantum system.

"Quantum computing could be potentially transformative, enabling us to solve problems that are impossible or impractical to solve today," said Arvind Krishna, senior vice president and director of IBM Research. "While quantum computers have traditionally been explored for cryptography, one area we find very compelling is the potential for practical quantum systems to solve problems in physics and quantum chemistry that are unsolvable today. This could have enormous potential in materials or drug design, opening up a new realm of applications."

For instance, in physics and chemistry, quantum computing could allow scientists to design new materials and drug compounds without expensive trial and error experiments in the lab, potentially speeding up the rate and pace of innovation across many industries.

For a world consumed by Big Data, quantum computers could quickly sort and curate ever larger databases as well as massive stores of diverse, unstructured data. This could transform how people make decisions and how researchers across industries make critical discoveries.

One of the great challenges for scientists seeking to harness the power of quantum computing is controlling or removing quantum decoherence – the creation of errors in calculations caused by interference from factors such as heat, electromagnetic radiation, and material defects. The errors are especially acute in quantum machines, since quantum information is so fragile.

"Up until now, researchers have been able to detect bit-flip or phase-flip quantum errors, but never the two together. Previous work in this area, using linear arrangements, only looked at bit-flip errors offering incomplete information on the quantum state of a system and making them inadequate for a quantum computer," said Jay Gambetta, a manager in the IBM Quantum Computing Group. "Our four qubit results take us past this hurdle by detecting both types of quantum errors and can be scalable to larger systems, as the qubits are arranged in a square lattice as opposed to a linear array."

The work at IBM was funded in part by the IARPA (Intelligence Advanced Research Projects Activity) multi-qubit-coherent-operations program.

Detecting quantum errors

The most basic piece of information that a typical computer understands is a bit. Much like a beam of light that can be switched on or off, a bit can have only one of two values: "1" or "0". However, a quantum bit (qubit) can hold a value of 1 or 0 as well as both values at the same time, described as superposition and simply denoted as "0+1". The sign of this superposition is important because both states 0 and 1 have a phase relationship to each other. This superposition property is what allows quantum computers to choose the correct solution amongst millions of possibilities in a time much faster than a conventional computer.

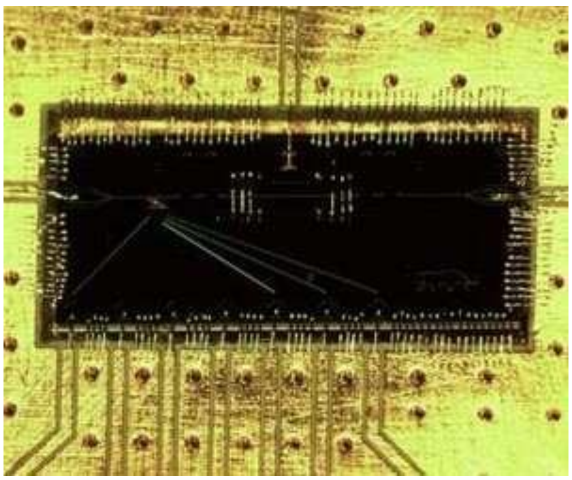
Two types of errors can occur on such a superposition state. One is called a bit-flip error, which simply flips a 0 to a 1 and vice versa. This is similar to classical bit-flip errors and previous work has showed how to detect these errors on qubits. However, this is not sufficient for quantum error correction because phase-flip errors can also be present, which flip the sign of the phase relationship between 0 and 1 in a superposition state. Both types of errors must be detected in order for quantum error correction to function properly.

Quantum information is very fragile because all existing qubit technologies lose their information when interacting with matter and electromagnetic radiation.
Theorists have found ways to preserve the information much longer by spreading information across many physical qubits. "Surface code" is the technical name for a specific error correction

scheme which spreads quantum information across many qubits. It allows for only nearest neighbor interactions to encode one logical qubit, making it sufficiently stable to perform error-free operations.

The IBM Research team used a variety of techniques to measure the states of two independent syndrome (measurement) qubits. Each reveals one aspect of the quantum information stored on two other qubits (called code, or data qubits). Specifically, one syndrome qubit revealed whether a bit-flip error occurred to either of the code qubits, while the other syndrome qubit revealed whether a phase-flip error occurred. Determining the joint quantum information in the code qubits is an essential step for quantum error correction because directly measuring the code qubits destroys the information contained within them. [8]

Next important step toward quantum computer



When facing big challenges, it is best to work together. In a team, the individual members can contribute their individual strengths - to the benefit of all those involved. One may be an absentminded scientist who has brilliant ideas, but quickly forgets them. He needs the help of his conscientious colleague, who writes everything down, in order to remind the scatterbrain about it later. It's very similar in the world of quanta.

There the so-called quantum dots (abbreviated: qDots) play the role of the forgetful genius. Quantum dots are unbeatably fast, when it comes to disseminating quantum information. Unfortunately, they forget the result of the calculation just as quickly - too quickly to be of any real use in a quantum computer.

In contrast, charged atoms, called ions, have an excellent memory: They can store quantum information for many minutes. In the quantum world, that is an eternity.

They are less well suited for fast calculations, however, because the internal processes are comparatively slow.

The physicists from Bonn and Cambridge have therefore obliged both of these components, qDots and ions, to work together as a team. Experts speak of a hybrid system, because it combines two completely different quantum systems with one another.

Absent-minded qDots

qDots are considered the great hopes in the development of quantum computers. In principle, they are extremely miniaturized electron storage units. qDots can be produced using the same techniques as normal computer chips. To do so, it is only necessary to miniaturize the structures on the chips until they hold just one single electron (in a conventional PC it is 10 to 100 electrons).

The electron stored in a qDot can take on states that are predicted by quantum theory. However, they are very short-lived: They decay within a few picoseconds (for illustration: in one picosecond, light travels a distance of just 0.3 millimeters).

This decay produces a small flash of light: a photon. Photons are wave packets that vibrate in a specific plane - the direction of polarization. The state of the qDots determines the direction of polarization of the photon. "We used the photon to excite an ion", explains Prof. Dr. Michael Kohl from the Institute of Physics at the University of Bonn. "Then we stored the direction of polarization of the photon".

Conscientious ions

To do so, the researchers connected a thin glass fiber to the qDot. They transported the photon via the fiber to the ion many meters away. The fiberoptic networks used in telecommunications operate very similarly. To make the transfer of information as efficient as possible, they had trapped the ion between two mirrors. The mirrors bounced the photon back and forth like a ping pong ball, until it was absorbed by the ion.

"By shooting it with a laser beam, we were able to read out the ion that was excited in this way", explains Prof. Kohl. "In the process, we were able to measure the direction of polarization of the previously absorbed photon". In a sense then, the state of the qDot can be preserved in the ion - theoretically this can be done for many minutes. [7]

Quantum Computing

A team of electrical engineers at UNSW Australia has observed the unique quantum behavior of a pair of spins in silicon and designed a new method to use them for "2-bit" quantum logic operations.

These milestones bring researchers a step closer to building a quantum computer, which promises dramatic data processing improvements.

Quantum bits, or qubits, are the building blocks of quantum computers. While many ways to create a qubits exist, the Australian team has focused on the use of single atoms of phosphorus, embedded inside a silicon chip similar to those used in normal computers.

The first author on the experimental work, PhD student Juan Pablo Dehollain, recalls the first time he realized what he was looking at.

"We clearly saw these two distinct quantum states, but they behaved very differently from what we were used to with a single atom. We had a real 'Eureka!' moment when we realized what was happening – we were seeing in real time the `entangled' quantum states of a pair of atoms." [5]

Researchers have developed the first silicon quantum computer building blocks that can process data with more than 99 percent accuracy, overcoming a major hurdle in the race to develop reliable quantum computers.

Researchers from the University of New South Wales (UNSW) in Australia have achieved a huge breakthrough in quantum computing - they've created two kinds of silicon quantum bit, or qubits, the building blocks that make up any quantum computer, that are more than 99 percent accurate.

The postdoctoral researcher who was lead author on Morello's paper explained in the press release: "The phosphorus atom contains in fact two qubits: the electron, and the nucleus. With the nucleus in particular, we have achieved accuracy close to 99.99 percent. That means only one error for every 10,000 quantum operations."

Both the breakthroughs were achieved by embedding the atoms in a thin layer of specially purified silicon, which contains only the silicon-28 isotope. Naturally occurring silicon is magnetic and therefore disturbs the quantum bit, messing with the accuracy of its data processing, but silicon-28 is perfectly non-magnetic. [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]

Conclusions

"With a memristor that can be tuned with a third electrode, we have the possibility to realize a function you could not previously achieve," Hersam said. "A three-terminal memristor has been proposed as a means of realizing brain-like computing. We are now actively exploring this possibility in the laboratory." [10]

"CQCL is at the forefront of developing an operating system that will allow users to harness the joint power of classical super computers alongside quantum computers," the company said in a press release. [9]

Because these qubits can be designed and manufactured using standard silicon fabrication techniques, IBM anticipates that once a handful of superconducting qubits can be manufactured reliably and repeatedly, and controlled with low error rates, there will be no fundamental obstacle to demonstrating error correction in larger lattices of qubits. [8]

This success is an important step on the still long and rocky road to a quantum computer. In the long term, researchers around the world are hoping for true marvels from this new type of computer: Certain tasks, such as the factoring of large numbers, should be child's play for such a computer. In contrast, conventional computers find this a really tough nut to crack. However, a quantum computer displays its talents only for such special tasks: For normal types of basic computations, it is pitifully slow. [7]

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 accelerated charges self-maintaining potential shows the locality of the relativity, working on the quantum level also. [1]

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. 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]
The key breakthrough to arrive at this new idea to build qubits was to exploit the ability to control the nuclear spin of each atom. With that insight, the team has now conceived a unique way to use the nuclei as facilitators for the quantum logic operation between the electrons. [5]
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 also.

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