Creating a Reference Map to Explore the Electronic Device Mimicking Brain Activity

Date: 14 January 2022

Source: Tohoku University

Summary: Maps are essential for exploring trackless wilderness or vast expanses of ocean. The same is true for scientific studies that try to open up new fields and develop brand-new devices. A journey without maps and signposts tends to end in vain.

In the world of 'neuromorphic devices', electronic devices that mimic neural cells, such as those in our brain, researchers have long been forced to travel without maps. Such devices will lead to a fresh field of brain-inspired computers with substantial benefits, such as low-energy consumption. But its operation mechanism has remained unclear, particularly in regards to controlling the response speed control.

A research group from Tohoku University and the University of Cambridge brought clarity in a recent study published in the journal *Advanced Electronic Materials* on 13 January 2022.

They looked into organic electrochemical transistors (OECTs), which are often used in neuromorphic devices to control the movement of the ion in the active layer.

Their analysis revealed that the response timescale depends on the size of ions in the electrolyte.

Based on these experimental results, the group modeled the neuromorphic response of the devices.

Comparisons of the data showed that movements of the ions in the OECTs control the response.

This indicates that tuning the timescale of ion movement can be an effective way to regulate the neuromorphic behaviour of OECTs.

"We obtained a map that provides rational design guidelines for neuromorphic devices by changing ion size and the material composition of the active layer," said Shunsuke Yamamoto, paper corresponding author and an assistant professor at Tohoku University's Graduate School of Engineering.

"Further studies will pave the way for applications in artificial neural networks and lead to better and more precise designs of the conducting polymer materials used in this field".

Musicians, Chemists use Sound to Better Understand Science

Date: 17 February 2022

Source: University of Illinois at Urbana-Champaign, News Bureau

Summary: Musicians are helping scientists analyse data, teach protein folding and make new discoveries through sound.

A team of researchers at the University of Illinois Urbana-Champaign is using sonification, the use of sound to convey information, to depict biochemical processes and better understand how they happen.

Music professor and composer Stephen Andrew Taylor, chemistry professor and biophysicist Martin Gruebele, and Illinois music and computer science alumna, composer and software designer Carla Scaletti formed the Biophysics Sonification Group, which has been meeting weekly on Zoom since the beginning of the pandemic. The group has experimented with using sonification in Gruebele's research into the physical mechanisms of protein folding and its work recently allowed Gruebele to make a new discovery about the ways a protein can fold.

Taylor's musical compositions have long been inspired by science, and recent works represent scientific data and biological processes. Gruebele is also a musician who built his own pipe organ that he plays and uses to compose music. The idea of collaborating on sonification struck a chord with them and they've been working together for several years. Through her company, Symbolic Sound Corporation, Scaletti develops a digital audio software and hardware sound design system called Kyma, that is used by many musicians and researchers, including Taylor.

Scaletti created an animated visualisation paired with sound to illustrate a simplified protein-folding process, and Gruebele and Taylor used it to introduce the key concepts of the process to students and gauge whether it helped with their understanding. They found that sonification complemented and reinforced the visualisations and that, even for experts, it helped increase intuition for how proteins fold and misfold over time. The Biophysics Sonification Group, which also includes chemistry professor Taras Pogorelov, former chemistry graduate student (now alumna) Meredith Rickard, composer and pipe organist Franz Danksagmüller of the Lübeck Academy of Music in Germany and Illinois electrical and computer engineering alumnus Kurt Hebel of Symbolic Sound, described their work about using sonification in teaching in the *Journal of Chemical Education*.

Gruebele and his research team use supercomputers to run simulations of proteins folding into a specific structure, a process that relies on a complex pattern of many interactions. The simulations reveal the multiple pathways the proteins take as they fold and also shows when they misfold or get stuck in the wrong shape, something thought to be related to a number of diseases, such as Alzheimer's and Parkinson's.

The researchers use the simulation data to gain insight into the process. Nearly all data analysis is done visually, Gruebele said, but massive amounts of data generated by the computer simulations representing hundreds of thousands of variables and millions of moments in time can be very difficult to visualise.

"In digital audio, everything is a stream of numbers, so, it's quite natural to take a stream of numbers and listen to it as if it's a digital recording," Scaletti said. "You can hear things that you wouldn't see if you looked at a list of numbers and you also wouldn't see if you looked at an animation. There's so much going on that there could be something that's hidden, but you could bring it out with sound."

For example, when the protein folds, it is surrounded by water molecules that are crucial for the process. Gruebele said that he wants to know when a water molecule touches and solvates a protein but "there are 50,000 water molecules moving around, and only one or two are doing a critical thing. It's impossible to see". However, if a sound, like splash, occurred every time a water molecule touched a specific amino acid, that would be easy to hear.

Taylor and Scaletti use various audio-mapping techniques to link aspects of proteins to sound parameters such as pitch, timbre, loudness and pan position. For example, Taylor's work uses different pitches and instruments to represent each unique amino acid, as well as their hydrophobic or hydrophilic qualities.

"I've been trying to draw on our instinctive responses to sound as much as possible," Taylor said. "Beethoven said, 'The deeper the stream, the deeper the tone.' We expect an elephant to make a low sound because it's big and we expect a sparrow to make a high sound because it's small. Certain kinds of mappings are built into us. We can take advantage of those instinctive mappings as much as possible to help in communicating effectively."

The highly developed instincts of musicians help in creating the best tool to use sound to convey information, Taylor said.

"It's a new way of showing how music and sound can help us understand the world. Musicians have an important role to play," he said. "It's helped me become a better musician, by encouraging me to think about sound in different ways and thinking how sound can link to the world in different ways, even at the microscopic level."

Study Suggests Association Between Consuming Artificial Sweeteners and Increased Cancer Risk

Date: 24 March 2022

Source: PLOS

Summary: Artificial sweeteners reduce added sugar content and corresponding calories while maintaining sweetness. A study published on March 24 in *PLOS Medicine* by Charlotte Debras and Mathilde Touvier at the French National Institute for Health and Medical Research (Inserm) and Sorbonne Paris Nord University, France and colleagues suggests that some artificial sweeteners are associated with increased cancer risk.

Many food products and beverages containing artificial sweeteners are consumed by millions of people daily. However, the safety of these additives has been a subject of debate. To evaluate the potential carcinogenicity of artificial sweeteners, researchers analysed data from 1,02,865 French adults participating in the NutriNet-Santé study. The NutriNet-Santé study is an ongoing web-based cohort initiated in 2009 by the Nutritional Epidemiology Research Team (EREN). Participants enrolled voluntarily and self-reported medical history, sociodemographic diet, lifestyle and health data. Researchers gathered data concerning artificial sweetener intake from 24-hour dietary records. After collecting cancer diagnosis information during follow-up, the researchers conducted statistical analyses to investigate the associations between artificial sweetener intakes and cancer risk. They also adjusted for a range of variables including age, sex, education, physical activity, smoking, body mass index, height, weight-gain during follow-up, diabetes, family history of cancer, as well as baseline intakes of energy, alcohol, sodium, saturated fatty acids, fibre, sugar, whole-grain foods and dairy products.

The researchers found that enrollees consuming larger quantities of artificial sweeteners, particularly aspartame and acesulfame-K, had higher risk of overall cancer compared to non-consumers (hazard ratio 1.13, 95% confidence interval 1.03 to 1.25). Higher risks were observed for breast cancer and obesity-related cancers.

The study had several important limitations; dietary intakes are self-reported. Selection bias may also have been a factor, as participants were more likely to be women, to have higher educational levels and to exhibit health-conscious behaviours. The observational nature of the study also means that residual confounding is possible and reverse causality cannot be ruled out. Additional research will be required to confirm the findings and clarify the underlying mechanisms.

According to the authors, "Our findings do not support the use of artificial sweeteners as safe alternatives for sugar in foods or beverages, and provide important and novel information to address the controversies about their potential adverse health effects. While these results need to be replicated in other large-scale cohorts and underlying mechanisms clarified by experimental studies, they provide important and novel insights for the ongoing re-evaluation of food additive sweeteners by the European Food Safety Authority and other health agencies globally."

Effects of Noise on Marine life

Date: 2 March 2022

Source: Woods Hole Oceanographic Institution

Summary: New research shows turtles can experience temporary hearing loss from an excess of underwater noise. This phenomenon, previously noted in other marine animals such as dolphins and fish, was not widely understood for reptiles and underscores another potential risk for aquatic turtles. This high volume of sound, referred to as underwater noise pollution, can be caused by passing ships and offshore construction.

"Our study is the first to support that these animals are vulnerable to underwater hearing loss after exposure to intense noise," said Andria Salas, WHOI *postdoctoral investigator* and study co-author. "We have assumed that turtles experience hearing loss when exposed to sufficiently intense sounds as observed in other animals, but there hasn't been any data collected specifically on turtles."

Aquatic turtles are predicted to rely on their sense of underwater hearing for environmental awareness, such as navigation or detection of possible predators, and some species have been shown to use underwater acoustic communication. Previous studies have focused on the effects of excessive noise in a range of animals, from squids to fishes to whales, and in both fresh and saltwater environments. But less work has been done on reptiles, like turtles, according to Salas.

The results of this study provide the first evidence of underwater noise-induced hearing loss in turtle species and suggest turtles may be more sensitive to sound than previously understood.

Salas and her collaborators, including WHOI *associate scientist* Aran Mooney, were surprised by how the turtles' hearing was impacted by a relatively low level of noise. The over exposure to noise induces temporary threshold shift (TTS), which refers to the decrease in the animal's hearing sensitivity. The absence of TTS studies in turtle species has led to a data gap for endangered sea turtles, and aquatic turtles more generally.

"If this occurs in nature, turtles would be less able to detect sounds in their environment on these timescales, including sounds used for communication or warning them of approaching predators," Salas said. "Over half of turtle and tortoise species are threatened, and noise pollution is an additional stressor to consider as we work towards protecting these animals."

"It was surprising that we found noise can induce underwater hearing loss in turtles, and then it was surprising that this hearing loss was at much lower levels than was estimated, so lots of surprises all around," said Mooney. "Also, the turtles remained pretty calm (or didn't show a behavioural response) despite the noise being loud enough to induce temporary hearing loss.

Notably, this temporary hearing loss is a normal physiological phenomenon in animals. We now see it across the board (mammals, birds, fish and reptiles). But importantly in this case, it can be a predictor of greater, more deleterious noise impacts such as permanent hearing loss or auditory damage."

Mathematical Paradoxes Demonstrate the Limits of AI

Date: 17 March 2022

Source: University of Cambridge

Summary: Humans are usually pretty good at recognising when they get things wrong, but artificial intelligence systems are not. According to a new study, AI generally suffers from inherent limitations due to a century-old mathematical paradox.

Like some people, AI systems often have a degree of confidence that far exceeds their actual abilities. And like an overconfident person, many AI systems do not know when they are making mistakes. Sometimes it is even more difficult for an AI system to realise when it is making a mistake than to produce a correct result.

Researchers from the University of Cambridge and the University of Oslo say that instability is the Achilles' heel of modern AI and that a mathematical paradox shows AI's limitations. Neural networks, the state of the art tool in AI, roughly mimic the links between neurons in the brain. The researchers show that there are problems where stable and accurate neural networks exist, yet no algorithm can produce such a network. Only in specific cases can algorithms compute stable and accurate neural networks.

The researchers propose a classification theory describing when neural networks can be trained to provide a trustworthy AI system under certain specific conditions. Their results are reported in the Proceedings of the National Academy of Sciences.

Deep learning, the leading AI technology for pattern recognition, has been the subject of numerous breathless headlines. Examples include diagnosing disease more accurately than physicians or preventing road accidents through autonomous driving. However, many deep learning systems are untrustworthy and easy to fool.

"Many AI systems are unstable, and it is becoming a major liability, especially as they are increasingly used in high-risk areas such as disease diagnosis or autonomous vehicles," said co-author Anders Hansen from Cambridge's Department of Applied Mathematics and Theoretical Physics. "If AI systems are used in areas where they can do real harm if they go wrong, trust in those systems has got to be the top priority."

The paradox identified by the researchers traces back to two 20th-century mathematical giants, Alan Turing and Kurt Gödel. At the beginning of the 20th century, mathematicians attempted to justify mathematics as the ultimate consistent language of science. However, Turing and Gödel showed a paradox at the heart of mathematics — it is impossible to prove whether certain mathematical statements are true or false, and some computational problems cannot be tackled with algorithms. And, whenever a mathematical system is rich enough to describe the arithmetic we learn at school, it cannot prove its own consistency.

Decades later, the mathematician Steve Smale proposed a list of 18 unsolved mathematical problems for the 21st century. The 18th problem concerned the limits of intelligence for both humans and machines.

"The paradox first identified by Turing and Gödel has now been brought forward into the world of AI by Smale and others," said co-author Matthew Colbrook from the Department of Applied Mathematics and Theoretical Physics. "There are fundamental limits inherent in mathematics and, similarly, AI algorithms can not exist for certain problems."

The researchers say that, because of this paradox, there are cases where good neural networks can exist, yet an inherently trustworthy one cannot be built. "No matter how accurate your data is, you can never get the perfect information to build the required neural network," said co-author Vegard Antun from the University of Oslo.

The impossibility of computing the good existing neural network is also true regardless of the amount of training data. No matter how much data an algorithm can access, it will not produce the desired network. "This is similar to Turing's argument: there are computational problems that cannot be solved regardless of computing power and runtime," said Hansen.

The researchers say that not all AI is inherently flawed, but it is only reliable in specific areas, using specific methods. "The issue is with areas where you need a guarantee, because many AI systems are a black box," said Colbrook. "It is completely fine in some situations for an AI to make mistakes, but it needs to be honest about it. And that is not what we are seeing for many systems — there is no way of knowing when they are more confident or less confident about a decision."

"Currently, AI systems can sometimes have a touch of guesswork to them," said Hansen."You try something, and if it does not work, you add more stuff, hoping it works. At some point, you will get tired of not getting what you want, and you will try a different method. It is important to understand the limitations of different approaches. We are at the stage where the practical successes of AI are far ahead of theory and understanding. A programme on understanding the foundations of AI computing is needed to bridge this gap."

"When 20th-century mathematicians identified different paradoxes, they did not stop studying mathematics. They just had to find new paths, because they understood the limitations," said Colbrook. "For AI, it may be a case of changing paths or developing new ones to build systems that can solve problems in a trustworthy and transparent way, while understanding their limitations."

The next stage for the researchers is to combine approximation theory, numerical analysis and foundations of computations to determine which neural networks can be computed by algorithms, and which can be made stable and trustworthy. Just as the paradoxes on the limitations of mathematics and computers identified by Gödel and Turing led to rich foundation theories — describing both the limitations and the possibilities of mathematics and computations — perhaps a similar foundations theory may blossom in AI.

Health Risk Due to Micro- and Nanoplastics in Food

Date: 24 March 2022

Source: Medical University of Vienna

Summary: Five grams of plastic particles on average enter the human gastrointestinal tract per person per week. This is roughly equivalent to the weight of a credit card. Whether ingested micro- and nanoplastics pose a health risk is being investigated in numerous studies but is largely unknown to date. A research team from MedUni Vienna has now summarised the current state of scientific knowledge. The review article has just been published in the journal *Exposure and Health*.

Medical research on the topic centres on the digestive system where micro- and nanoplastic particles (MNPs) can be found in tissue.

Experimental studies indicate that ingested MNPs passing through the gastrointestinal tract lead to changes in the composition of the gut microbiome.

The research team led by Elisabeth Gruber (Division of Visceral Surgery of MedUni Vienna's Department for General Surgery) and Lukas Kenner (Department of Pathology MedUni Vienna, Comprehensive Cancer Centre (CCC) MedUni Vienna and Vienna General Hospital, Department of Laboratory Animal Pathology of VetMedUni) report that such changes are associated with the development of metabolic diseases such as diabetes, obesity or chronic liver disease.

In addition to the effects on the gut microbiome, scientists also described specific molecular mechanisms that facilitate the uptake of MNPs into gut tissue.

Using specific analyses, it was shown that MNPs in the gastrointestinal tract could increasingly be taken up into tissue under certain physicochemical conditions and activate mechanisms involved in local inflammatory and immune responses.

Nanoplastics in particular are associated with biochemical processes that are crucially involved in carcinogenesis.

Plastic particles also in drinking water

Nanoplastics are defined as being less than 0.001 millimetre in size, while microplastics, at 0.001 to 5 millimetres, are to some extent still visible to the naked eye.

MNPs enter the food chain from packaging waste, among other sources.

The plastic particles are not only trafficked into the body via food such as marine life or sea salt in particular, drinking also plays a part.

According to a study, anyone who drinks the recommended 1.5 to 2 litres of water a day from plastic bottles ingests around 90,000 plastic particles per year in this way alone.

However, those who choose tap water can, depending on their geographical location, reduce the amount ingested to 40,000 plastic particles.

Researchers also demonstrated widespread contamination of mineral water with xenohormones leached from PET (polyethylene terephthalate) bottles.

Xenohormones are known to exhibit oestrogenic activity which can act carcinogenic in the body.

The potential adverse health effects of plastic particles could be particularly harmful for people with a chronic disease burden, says Lukas Kenner. "A healthy gut is more likely to ward off the health risk. But local changes in the gastrointestinal tract, such as those present in chronic disease or even negative stress, could make them susceptible to the harmful effects of MNPs."

Bacteria Generate Electricity from Methane

Date: 12 April 2022

Source: Radboud University Nijmegen

Summary: The bacteria, *Candidatus* Methanoperedens, use methane to grow and naturally occur in fresh water such as ditches and lakes.

In the Netherlands, the bacteria mostly thrive in locations where the surface and groundwater are contaminated with nitrogen, as they require nitrate to break down methane.

The researchers initially wanted to know more about the conversion processes occurring in the microorganism.

In addition, they were also curious whether it would be possible to use it to generate power.

"This could be very useful for the energy sector," says microbiologist and author Cornelia Welte.

"In the current biogas installations, methane is produced by microorganisms and subsequently burnt, which drives a turbine, thus generating power. Less than half of the biogas is converted into power, and this is the maximum achievable capacity. We want to evaluate whether we can do better using microorganisms."

A kind of battery

Fellow microbiologists from Nijmegen have previously shown that it is possible to generate power using anammox bacteria that use ammonium during the process instead of methane.

"The process in these bacteria is basically the same," says microbiologist Heleen Ouboter.

"We create a kind of battery with two terminals, where one of these is a biological terminal and the other one is a chemical terminal. We grow the bacteria on one of the electrodes, to which the bacteria donate electrons resulting from the conversion of methane."

Jupiter's Moon has Splendid Dunes

Date: 19 April 2022

Source: Rutgers University

Summary: Scientists have long wondered how Jupiter's innermost moon, Io, has meandering ridges as grand as any that can be seen in movies like "Dune". Now, a Rutgers research study has provided a new explanation of how dunes can form even on a surface as icy and roiling as Io's.

The study, published in the journal *Nature Communications*, is based on a study of the physical processes controlling grain motion coupled with an analysis of images from the 14-year mission of NASA's Galileo spacecraft, which allowed the creation of the first detailed maps of Jupiter's moons. The new study is expected to expand our scientific understanding of the geological features on these planet-like worlds.

"Our studies point to the possibility of Io as a new 'dune world,'" said first author George McDonald, a *postdoctoral researcher* in Rutgers' Earth and Planetary Sciences Department. "We have proposed, and quantitatively tested, a mechanism by which sand grains can move, and in turn dunes could be forming there."

Current scientific understanding dictates that dunes, by their nature, are hills or ridges of sand piled up by the wind. And scientists in previous studies of Io, while describing its surface as containing some dune-like features, concluded the ridges could not be dunes since the forces from winds on Io are weak due to the moon's low-density atmosphere.

"This work tells us that the environments in which dunes are found are considerably more varied than the classical, endless desert landscapes on parts of Earth or on the fictional planet Arrakis in 'Dune,'" McDonald said.

The Galileo mission, which lasted from 1989 — 2003, logged so many scientific firsts that researchers to this day are still studying the data it collected. One of the major insights gleaned from the data was the high extent of volcanic activity on Io; so much so that its volcanoes repeatedly and rapidly resurface the little world.

Io's surface is a mix of black solidified lava flows and sand, flowing "effusive" lava streams and "snows" of sulfur dioxide. The scientists used mathematical equations to simulate the forces on a single grain of basalt or frost and calculate its path. When lava flows into sulfur dioxide beneath the moon's surface, its venting is "dense and fast moving enough to move grains on Io and possibly enable the formation of large-scale features like dunes," McDonald said.

Once the researchers devised a mechanism by which the dunes could form, they looked at the photos of Io's surface taken by the Galileo spacecraft for more proof. The spacing of the crests and the height-to-width ratios they observed were consistent with trends for dunes seen on Earth and other planets.