IT Matters

Smartphone sensors become antimatter camera

At CERN, scientists from the AEgIS collaboration led by a team of the Technical University of Munich (TUM) have repurposed smartphone camera sensors to create a detector capable of tracking antiproton annihilations in real time with unprecedented resolution. This new device, described in a paper just published, can pinpoint antiproton annihilations with a resolution of about 0.6 micrometres, a 35-fold improvement over previous real-time methods.

Scientists working at the "Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy" (AEgIS) and other experiments at CERN's Antimatter Factory, such ALPHA and GBAR, are on a mission to measure the free-fall of antihydrogen under Earth's gravity with high precision, each using a different technique.

AEgIS's approach involves producing a horizontal beam of antihydrogen and measuring its vertical displacement using a device called a moiré deflectometer that reveals tiny deviations in motion and a detector that records the antihydrogen annihilation points. "For AEgIS to work, we need a detector with incredibly high spatial resolution, and mobile camera sensors have pixels smaller than 1 micrometer," says Francesco Guatieri from the research neutron source FRM II at TUM and Principal Investigator of the research.

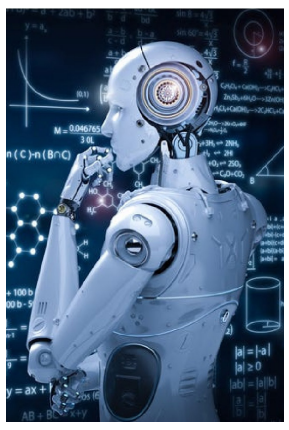
Overdependence on AI risk for science?

Researchers from chemistry, biology, and medicine are increasingly turning to AI models to develop new hypotheses. However, it is often unclear on which basis the algorithms come to their conclusions and to what extent they can be generalised. A publication by the University of Bonn now warns of misunderstandings in handling artificial intelligence. At the same time, it highlights the conditions under which researchers can most likely have confidence in the models.

Adaptive machine learning algorithms are incredibly powerful. Nevertheless, they have a disadvantage: How machine learning models arrive at their predictions is often not apparent from the outside.

Suppose you feed artificial intelligence with photos of several thousand cars. If you now present it with a new image, it can usually identify reliably whether the picture also shows a car or not. But why is that? Has it really learned that a car has four wheels, a windshield, and an exhaust? Or is its decision based on criteria that are actually irrelevant - such as the antenna on the roof? If this were the case, it could also classify a radio as a car.

"AI models are black boxes," highlights Prof. Dr. Jürgen Bajorath. "As a result, one should not blindly trust their results and draw conclusions from them." The computational chemistry expert heads the AI in Life Sciences department



at the Lamarr Institute for Machine Learning and Artificial Intelligence. He is also in charge of the Life Science Informatics program at the Bonn-Aachen International Center for Information Technology (b-it) at the University of Bonn. In the current publication, he investigated the question of when one can most likely rely on the algorithms. And vice versa: When not.

The concept of "explainability" plays an important role in this context. Metaphorically speaking, this refers to efforts within AI research to drill a peephole into the black box. The algorithm should reveal the criteria that it uses as a basis - the four wheels or the antenna. "Opening the black box currently is a central topic in AI research," says Bajorath. " Some AI models are exclusively developed to make the results of others more comprehensible."

Explainability, however, is only one aspect - the question of which conclusions might be drawn from the decision-making criteria chosen by a model is equally important. If the algorithm indicates that it has based its decision on the antenna, a human being knows immediately that this feature is poorly suited for identifying cars. Despite this, adaptive models are generally used to identify correlations in large data sets that humans might not even notice. We are then like aliens who do not know what makes a car: An alien would be unable to say whether or not an antenna is a good criterion.

"There is another question that we always have to ask ourselves when using AI procedures in science," stresses Bajorath, who is also a member of the Transdisciplinary Research Area (TRA) "Modelling": "How interpretable are the results?" Chemical language models currently are a hot topic in chemistry and pharmaceutical research. It is possible, for instance, to feed them with many molecules that have a certain biological activity. Based on these input data, the model then learns and ideally suggests a new molecule that also has this activity but a new structure. This is also referred to as generative modeling. However, the model can usually not explain why it comes to this solution. It is often necessary to subsequently apply explainable AI methods.

Nonetheless, Bajorath warns against over-interpreting these explanations, that is, anticipating that features the AI considers important indeed cause the desired activity. "Current AI models understand essentially nothing about chemistry," he says. "They are purely statistical and correlative in nature and pay attention to any distinguishing features, regardless of whether these features might be chemically or biologically relevant or not."

Study unveils new strategy for wave control

Researchers at the Advanced Science Research Centre at the CUNY Graduate Center (CUNY ASRC) and at Florida International University recently reported their insights on the emerging field of complex frequencies excitations, a recently introduced scheme to control light, sound and other wave phenomena beyond conventional limits. Based on this approach, they outline opportunities that advance fundamental understanding of wave-matter interactions and usher wave-based technologies into a new era.

In conventional light wave and sound wave-based systems such as wireless cell phone technologies, microscopes, speakers and earphones, the control over wave phenomena is limited by constraints, which stem from the fundamental properties of the materials used in these technologies. Overcoming these constraints typically requires the use of exotic materials, adding energy to the system, and or making the devices more complex and cumbersome. Complex frequency excitations offer an alternative approach to enhance wave control using conventional materials. By tailoring the excitation form, rather than the materials themselves, to oscillate at complex-valued frequencies, it is possible to emulate the presence of gain and loss in the system, unlocking exotic effects such as perfect absorption, super-resolution imaging, surpass passivity limitations in wave-matter interactions, and access non-Hermitian responses, without having to rely on active complex components that require energy and are prone to instabilities."This approach provides a fundamentally new strategy for wave control," said the study's principal investigator Andrea Alù, Distinguished Professor and Einstein Professor of Physics at The City University of New York Graduate Center and founding director of the CUNY ASRC Photonics Initiative. "We are no longer limited by the material platform to enhance the device performance. We can now shape how wave-based systems respond simply by designing the right kinds of excitations."

12,900 km ultra-secure quantum satellite link

Scientists from South Africa and China have successfully established the world's longest intercontinental ultra-secure quantum satellite link, spanning 12,900 km. Using the Chinese quantum microsatellite Jinan-1, launched into low Earth orbit, this milestone marks the first-ever quantum satellite communication link established in the Southern Hemisphere.

In this demonstration, quantum keys were generated in real-time through Quantum Key Distribution (QKD), enabling the secure encryption of images transmitted between ground stations in China and South Africa via one-time pad encryption - considered unbreakable. The results from this pioneering experiment from a collaborative research initiative between scientists from Stellenbosch University (South Africa) and the University of Science and Technology of China were published recently.

Stellenbosch's ideal environmental conditions - clear skies and low humidity - allowed the local ground station to achieve an exceptional key generation rate of 1.07 million secure bits during a single satellite pass.

Quantum communication leverages fundamental principles of quantum mechanics, guaranteeing highly secure information transfer. Quantum Key Distribution, a critical component, employs single photons to encode and transmit secure keys. Because single photons cannot be intercepted, copied, or measured without altering their quantum states, this technology provides unparalleled security, even against powerful adversaries.

China has impressive accomplishments in quantum communication technology, guided by quantum physicist Prof Jian-Wei Pan. The country's extensive quantum infrastructure includes a 2,000 km terrestrial fibre-based quantum network connecting 32 trusted nodes across major cities, from Beijing to Shanghai. Prof Juan Yin was instrumental in developing China's first quantum satellite, Micius, previously demonstrated groundbreaking satellite-based quantum links, including a notable 7,600 km intercontinental link between China and Austria in 2017. For this South Africa-China collaboration, Prof Juan Yin again led the Chinese research team.

The South African research team at Stellenbosch University's Department of Physics was led by Dr Yaseera Ismail, the lead experimentalist responsible for successfully establishing the quantum satellite link. Prof Francesco Petruccione, Professor of Quantum Computing in the School of Data Science and Computational Thinking and Director of the National Institute for Theoretical and Computational Sciences (NITheCS) at Stellenbosch University, pioneered quantum communication in South Africa, notably developing one of the world's first fibre-optic quantum communication networks in Durban.

Exception to laws of thermodynamics

A team of researchers led by a physics graduate student at the University of Massachusetts Amherst recently made the surprising discovery of what they call a "shape-recovering liquid," which defies some long-held expectations derived from the laws of thermodynamics. The research, published recently, details a mixture of oil, water and magnetized particles that, when shaken, always quickly separates into what looks like the classically curvaceous lines of a Grecian urn.

"Imagine your favorite Italian salad dressing," says Thomas Russell, Silvio O. Conte Distinguished Professor of Polymer Science and Engineering at UMass Amherst and one of the paper's senior authors. "It's made up of oil, water and spices, and before you pour it onto your salad, you shake it up so that all the ingredients mix." It's those spices, those small bits of something else, that allow water and oil, which are normally mutually exclusive, to mix, a process called emulsification and which is described by the laws of thermodynamics.

Emulsification underlies a vast range of technologies and applications far beyond condiments, and one day, UMass Amherst graduate student Anthony Raykh was in the lab mixing up a batch of this scientific "salad dressing" to see what he could create -- only instead of spices, he was using magnetized particles of nickel, "because you can engineer all sorts of interesting materials with useful properties when a fluid contains magnetic particles," says Raykh. He made his mixture, shook it up -- "and, in a complete surprise, the mixture formed this beautiful, pristine urn-shape." No matter how many times or how hard he shook, the urn shape always returned.