Human Skin Pigmentation Recreated with a 3-D Bio Printer

A new method for controlling pigmentation in fabricated human skin has been developed by researchers from A*STAR's Singapore Institute of Manufacturing Technology (SIMTech) and the Singapore Centre for 3D Printing (SC3DP) at Nanyang Technological University.

In their paper in *Biofabrication,* the team showed how they utilised 3D bioprinting to control the distribution of melanin-producing skin cells (melanocytes) on a *biomimetic* tissue substrate, to produce human-like skin pigmentation.

While engineered skin constructs are successfully used in skin repair and grafting, toxicology, and chemical testing, they lack complex features such as skin pigmentation, sweat glands or hair follicles.

Lead author Wei Long Ng aimed to overcome these challenges in a joint project initiated by SIMTech's May Win Naing and SC3DP's Wai Yee Yeong. Wei Long said: "3D bioprinting

is an excellent platform for the precise deposition of biomaterials and living cells to make biomimetic skin, in large volumes with great repeatability. However, non-uniform skin pigmentation is often seen, and this remains a huge challenge to be solved.

"Our aim with this project was to use this method to demonstrate the feasibility of making 3D in-vitro pigmented human skin constructs, with uniform skin pigmentation."

To make the pigmented skin constructs, the team used three different types of skin cells — keratinocytes, melanocytes, and fibroblasts — and a two-step 'drop on demand' bioprinting method.

Wei Long Ng explained: "The two-step bioprinting strategy involves the fabrication of hierarchical porous collagen-based structures (that closely resembles the skin's dermal region), and deposition of epidermal cells such as keratinocytes and melanocytes at pre-defined positions on top of the biomimetic dermal skin constructs, to create 3D in-vitro pigmented human skin constructs."When we compared the 3D bioprinted skin constructs to those made

using a manual-casting method, we found two distinct differences between the two fabrication approaches — the cell distribution on top of the dermal regions, and the microstructures within the dermal regions. The two-step bioprinting strategy enables the standardised distribution of printed cells in a highly-controlled way, as compared to the manual casting approach."

He added: "Furthermore, the bioprinting technique allows the manipulation of pore sizes within the 3D collagen-fibroblast matrices, to fabricate hierarchical porous structures that are clearly seen in the native skin tissues. In contrast, tuning the skin microstructure within the 3D collagen-fibroblast matrices using the manual-casting approach is extremely challenging."

As well as the potential to produce pigment-correct skin grafts, the team's 3D bioprinting method could also be used to develop skin constructs for toxicology testing and fundamental cell biology research.

The Down Syndrome 'Super Genome'

Down syndrome — also known as Trisomy 21 — is a genetic disorder caused by an additional third chromosome 21. Although this genetic abnormality is found in one out of 700 births, only 20 per cent of foetuses with Trisomy 21 reach full term. But how do they manage to survive the first trimester of pregnancy despite this heavy handicap? Researchers from the Universities of Geneva (UNIGE) and Lausanne (UNIL) have found that children born with Down syndrome have an excellent genome in many ways — better, in fact, than the average genome of people

without the genetic abnormality. It is possible that this genome offsets the disabilities caused by the extra chromosome, helping the fetus to survive and the child to grow and develop. You can find out more about these discoveries in the journal *Genome Research.*

Trisomy 21 is a serious genetic disorder, with four pregnancies out of five not reaching term naturally if the fetus is affected. However, 20 per cent of conceptuses with Down syndrome are born live, grow up and can reach the age of 65. How is this possible? Researchers from UNIGE and UNIL hypothesised that individuals born with Down syndrome possess a high quality genome that has the ability to compensate for the effects of the third chromosome 21.

Variation, Regulation and Expression All Tested

"The genome consists of all the genetic material that makes up an individual," explains StylianosAntonarakis, the honorary professor in UNIGE's Faculty of Medicine who led the research. "It's the genome that determines what becomes of a person, and makes him or her grow up and grow old, with or without disease. Some genomes are of better quality than others, and can also be less prone to illnesses such as cancer." Basing their work on the hypothesis of the quality of the genome, the geneticists tested the gene variation, regulation and expression of 380 individuals with Down syndrome and compared them to people without the genetic disorder.

The first test consisted of observing the presence of rare variants, i.e., potentially harmful genetic mutations, in people with Down. It is known that a chromosome can have different rare variants in its two copies. In a person with Down, however,

the rare mutations that are identical for all three copies of chromosome 21 and limited in number, thereby reducing the total of potentially deleterious variants.

In a next step the geneticists have studied the regulation of genes on chromosome 21. Each gene has switches that regulate its expression either positively or negatively. Since people with Down have three chromosomes 21, most of these genes are overexpressed. "But we discovered that people with Down syndrome have more regulators that diminish the expression of the 21 genes, making it possible to compensate for the surplus induced by the third copy," says Konstantin Popadin, a researcher at UNIL's Center for Integrative Genomics.

Finally, the researchers focused on the variation gene expression for the chromosomes of the entire genome. Each gene expression on a scale from 0 to 100 forms part of a global spread curve, with the median — 50 — considered the ideal expression. "For a normal genome, the expressions oscillate between 30 and 70, while for a person with Down syndrome, the curve is narrower around the peak that is very close to 50 for genes on all the chromosomes," continues professor Antonarakis. "In other words, this means that the genome of someone with Down leans towards the average — optimal functioning." Indeed, the smaller the gene expression variations are, the better the genome.

A Superior Genome that Compensates for the Disability

The UNIGE and UNIL geneticists were thus able to test the three functions of genomes of people suffering from Down syndrome. "The research has shown that for a child with Down to survive pregnancy and then grow, his or her genome must be of a higher quality so that it can compensate for the disabilities caused by the extra copy of chromosome 21," concludes Popadin. These conclusions may also apply to other serious genetic disorders where pregnancies reach full term.

Curcumin Improves Memory and Mood

Twice-daily Supplements Boosted Cognitive Power over 18 Months

Lovers of Indian food, give yourselves a second helping: Daily consumption of a certain form of curcumin — the substance that gives Indian curry its bright color — improved memory and mood in people with mild, age-related memory loss, according to the results of a study conducted by UCLA researchers.

The research, published online in the January 2019 *American Journal of Geriatric Psychiatry,* examined the effects of an easily absorbed curcumin supplement on memory performance in people without dementia, as well as curcumin's potential impact on the microscopic plaques and tangles in the brains of people with Alzheimer's disease.

Found in turmeric, curcumin has previously been shown to have anti-inflammatory and antioxidant properties in lab studies. It also has been suggested as a possible reason that senior citizens in India, where curcumin is a dietary staple, have a lower prevalence of Alzheimer's disease and better cognitive performance.

"Exactly how curcumin exerts its effects is not certain, but it may be due to its ability to

reduce brain inflammation, which has been linked to both Alzheimer's disease and major depression," said Dr. Gary Small, director of geriatric psychiatry at UCLA's Longevity Center and of the geriatric psychiatry division at the Semel Institute for Neuroscience and Human Behavior at UCLA, and the study's first author.

The double-blind, placebo-controlled study involved 40 adults between the ages of 50 and 90 years who had mild memory complaints. Participants were randomly assigned to receive either a placebo or 90 milligrams of curcumin twice daily for 18 months.

All 40 subjects received standardized cognitive assessments at the start of the study and at six-month intervals, and monitoring of curcumin levels in their blood at the start of the study and after 18 months. Thirty of the volunteers underwent positron emission tomography, or PET scans, to determine the levels of amyloid and tau in their brains at the start of the study and after 18 months.

The people who took curcumin experienced significant improvements in their memory and attention abilities, while the subjects who received placebo did not, Small said. In memory tests, the people taking curcumin improved by 28 per cent over the 18 months. Those taking curcumin also had mild improvements in mood, and their brain PET scans showed significantly less amyloid and tau signals in the amygdala and hypothalamus than those who took placebos.

The amygdala and hypothalamus are regions of the brain that control several memory and emotional functions.

Four people taking curcumin, and two taking placebos, experienced mild side effects such as abdominal pain and nausea.

The researchers plan to conduct a follow-up study with a larger number of people. That study will include some people with mild depression so the scientists can explore whether curcumin also has antidepressant effects. The larger sample also would allow them to analyse whether curcumin's memory-enhancing effects vary according to people's genetic risk for Alzheimer's, their age or the extent of their cognitive problems.

"These results suggest that taking this relatively safe form of curcumin could provide meaningful cognitive benefits over the years," said Small, UCLA's Parlow-Solomon Professor on Aging.

Nature Has More Than One Way to Make Methane

Methane is a potent greenhouse gas, trapping more solar radiation on earth than carbon dioxide. It is also the primary component of natural gas, a critical fuel source for heating and other uses. For these reasons and more, scientists are keenly interested in how the gas is made.

A long-held assumption is that methane made by living organisms is made exclusively by a process called methanogenesis. Not so fast, say Utah State University and University of Washington biochemists, who report a bacterial, iron-only nitrogenase pathway for methane formation. Further the iron-only variant of nitrogenase can transform carbon dioxide into methane in a single, enzymatic step.

USU biochemists Lance Seefeldt, Derek Harris, Rhesa Ledbetter and Zhi-Yong Yang, along with collaborators Carrie Harwood,

Mary Lidstrom, YanningZheng, Zheng Yu, Yanfen Fu and Katie Fixen of the University of Washington; as well as SarojPoudel and Eric Boyd of Montana State University, published findings in the 15 January, 2018, advance online publication of *Nature Microbiology.*

"Our findings are significant because they give scientists a second target to chase in understanding biological methane formation and rising methane emissions," says Seefeldt, professor in USU's Department of Chemistry and Biochemistry. "In addition, the discovery could drive efforts to turn waste gasses into usable fuels."

The ability to accomplish large-scale capture of environmentally damaging byproducts from burning fossil fuel combustion into clean, alternative fuels has far-reaching benefits, he says.

"It's a 'holy grail' of energy science," says Seefeldt, an American Association for the Advancement of Science Fellow. "The knowledge we're gradually gaining could be used to make fuels from waste gases, helping to improve the environment."

New Drug Capsule May Allow Weekly HIV Treatment

Replacing daily pills with a weekly regimen could help patients stick to their dosing schedule

Researchers at MIT and Brigham and Women's Hospital have developed a capsule that can deliver a week's worth of HIV drugs in a single dose. This advance could make it much easier for patients to adhere to the strict schedule of dosing required for the drug cocktails used to fight the virus, the researchers say.

The new capsule is designed so that patients can take it just once a week, and the drug will release gradually throughout the week. This type of delivery system could not only improve patients' adherence to their treatment schedule but also be used by people at risk of HIV exposure to help prevent them from becoming infected, the researchers say.

"One of the main barriers to treating and preventing HIV is adherence," says Giovanni Traverso, a research affiliate at MIT's Koch Institute for Integrative Cancer Research and a gastroenterologist and biomedical engineer at Brigham and Women's Hospital. "The ability to make doses less frequent stands to improve adherence and make a significant impact at the patient level."

Traverso and Robert Langer, the David H. Koch Institute Professor at MIT, are the senior authors of the study, which appears in the 9 January issue of *Nature Communications.* MIT postdoc AmeyaKirtane and visiting scholar Omar Abouzid are the lead authors of the paper.

Scientists from Lyndra, a company that was launched to develop this technology, also contributed to the study. Lyndra is now working toward performing a clinical trial using this delivery system.

"We are all very excited about how this new drug-delivery system can potentially help patients with HIV/AIDS, as well as many other diseases," Langer says.

"A pillbox in a capsule"

Although the overall mortality rate of HIV has dropped significantly since the introduction of antiretroviral therapies in the 1990s, there were 2.1 million new HIV infections and 1.2 million HIV-related deaths in 2015.

Several large clinical trials have evaluated whether antiretroviral drugs can prevent HIV infection in healthy populations. These trials have had mixed success, and one major obstacle to preventative treatment is the difficulty in getting people to take the necessary pills every day.

The MIT/BWH team believed that a drug delivery capsule they developed in 2016 might help to address this problem. Their capsule consists of a star-shaped structure with six arms that can be loaded with drugs, folded inward, and encased in a smooth coating. After the capsule is swallowed, the arms unfold and gradually release their cargo.

In a previous study, the researchers found that these capsules could remain in the stomach for up to two weeks, gradually releasing the drug *ivermectin.* The researchers then set out to adapt the capsule to deliver HIV drugs.

In their original version, the entire star shape was made from one polymer that both provides structural support and carries the drug payload. This made it more difficult to design new capsules that would release drugs at varying rates, because any changes to the polymer composition might disrupt the capsule's structural integrity.

To overcome that, the researchers designed a new version in which the backbone of the star structure is still a strong polymer, but each of the six arms can be filled with a different drug-loaded polymer. This makes it easier to design a capsule that releases drugs at different rates.

"In a way, it's like putting a pillbox in a capsule. Now you have chambers for every day of the week on a single capsule," Traverso says.

Tests in pigs showed that the capsules were able to successfully lodge in the stomach and release three different HIV drugs over one week. The capsules are designed so that after all of the drug is released, the capsules disintegrate into smaller components that can pass through the digestive tract.

Preventing Infection

Working with the Institute for Disease Modeling in Bellevue, Washington, the researchers tried to predict how much impact a weekly drug could have on preventing HIV infections. They calculated that going from a daily dose to a weekly dose could improve the efficacy of HIV preventative treatment by approximately 20 per cent. When this figure was incorporated into a computer model of HIV transmission in South Africa, the model showed that 200,000 to 800,000 new infections could be prevented over the next 20 years.

"A longer-acting, less invasive oral formulation could be one important part of our future arsenal to stop the HIV/AIDS pandemic," says Anthony Fauci, director of the National Institute of Allergy and Infectious Disease, which partly funded the research.

"Substantial progress has been made to advance antiretroviral therapies, enabling a person living with HIV to achieve a nearly normal lifespan and reducing the risk of acquiring HIV. However, lack of adherence to once-daily therapeutics for infected individuals and pre-exposure prophylaxis (PrEP) for uninfected at-risk people remain a key challenge. New and improved tools for HIV treatment and prevention, along with wider implementation of novel and existing approaches, are needed to end the HIV pandemic as we know it. Studies such as this

help us move closer to achieving this goal," Fauci says.

The MIT/BWH team is now working on adapting this technology to other diseases that could benefit from weekly drug dosing. Because of the way that the researchers designed the polymer arms of the capsule, it is fairly easy to swap different drugs in and out, they say.

"To put other drugs onto the system is significantly easier because the core system remains the same," Kirtane says. "All we need to do is change how slowly or how quickly it will be released."

The researchers are also working on capsules that could stay in the body for much longer periods of time.

The research was also funded by the Bill and Melinda Gates Foundation, Bill and Melinda Gates through the Global Good Fund, the National Institutes of Health, and the Division of Gastroenterology at Brigham and Women's Hospital.

E-cigarette Flavours are Toxic to White Blood Cells, Warn Scientists

Cinnamon, vanilla and buttery e-cigarette flavours are among the most toxic — and mixing flavours is more damaging than vaping just one

Sugar and spice are not so nice, at least when it comes to vaping or inhalation. Exposure to e-cigarette flavouring chemicals and liquids can cause significant inflammation to monocytes, a type of white blood cell — and many flavouring compounds are also toxic, with cinnamon, vanilla and buttery flavours among the worst. That's the finding of new

research published in open-access journal *Frontiers in Physiology,* which also found that mixing e-cigarette flavours has a much worse effect than exposure to just one. The study adds to growing evidence on the harmful health effects of e-cigarettes.

The use of e-cigarettes has exploded in the past decade as traditional cigarette consumption has declined. In the United States alone, more than 500 e-cigarette brands with almost 8,000 uniquely flavoured e-juices are available to consumers.

Vaping exposes the lungs to flavouring chemicals when the e-liquids are heated and inhaled. Since the flavouring chemicals are considered safe to eat, e-cigarettes are often considered — and advertised — as a healthier alternative to traditional cigarettes. However, the health effects of inhaling these chemicals are not well understood.

This new study, led by researchers at the University of Rochester Medical Centre in the United States, wanted to test the assumption that vaping nicotine-free flavoured e-liquids is safer than smoking conventional cigarettes. Previous studies show that flavours used in e-cigarettes cause inflammatory and oxidative stress responses in lung cells. Users of e-cigarettes also show increased levels oxidative stress markers in the blood compared to non-smokers. The new study extends this to assess the effects of commonly used flavouring chemicals, as well as e-liquids without nicotine, directly on immune cells — namely, a type of white blood cell called monocytes.

Exposure to the e-cigarette flavouring chemicals and e-liquids led to higher production of two well-established biomarkers for inflammation and tissue

damage mediated by oxidative stress. Furthermore, many of the flavouring chemicals caused significant cell death — with some flavours being more toxic than others.

The study's first author, Dr Thivanka Muthumalage says that while the flavouring compounds tested may be safe for ingestion, these results show they are not safe for inhalation. "Cinnamon, vanilla and butter flavoring chemicals were the most toxic but our research showed that mixing flavours of e-liquids caused by far the most toxicity to white blood cells."

Senior author, Dr Irfan Rahman, says he hopes this new data will provide insights into understanding the harmful effects of flavoured e-juices without nicotine.

"Currently, these are not regulated, and alluring flavor names, such as candy, cake, cinnamon roll and mystery mix, attract young vapers," he says. "Our scientific findings show that e-liquid flavors can, and should, be regulated and that e-juice bottles must have a descriptive listing of all ingredients. We urge regulatory agencies to act to protect public health."

This study directly exposed monocytic blood cells to e-liquids. The authors plan to undertake further research to simulate live vaping, by exposing cells to e-liquid aerosols in an air-liquid interface system. They also call for further long-term human studies to assess the harmful effects of e-cigarettes.

Human Neural Stem Cell Grafts to Repair Spinal Cord Injuries in Monkeys

Findings represent major and essential step toward future human clinical trials

Led by researchers at University of California San Diego School of Medicine, a diverse team of neuroscientists and surgeons successfully grafted human neural progenitor cells into rhesus monkeys with spinal cord injuries. The grafts not only survived, but grew hundreds of thousands of human axons and synapses, resulting in improved forelimb function in the monkeys

The findings, published online in the 26 February issue of *Nature Medicine,* represent a significant step in translating similar, earlier work in rodents closer to human clinical trials and a potential remedy for paralysing spinal cord injuries in people.

"For more than three decades, spinal cord injury research has slowly moved toward the elusive goal of abundant, long-distance regeneration of injured axons, which is fundamental to any real restoration of physical function," said Mark Tuszynski, MD, PhD, professor of neuroscience and director of the UC San Diego Translational Neuroscience Institute.

"While there was real progress in research using small animal models, there were also enormous uncertainties that we felt could only be addressed by progressing to models

more like humans before we conduct trials with people," Tuszynski said.

"We discovered, for example, that the grafting methods used with rodents didn't work in larger, non-human primates. There were critical issues of scale, immunosuppression, timing and other features of methodology that had to be altered or invented. Had we attempted human transplantation without prior large animal testing, there would have been substantial risk of clinical trial failure, not because neural stem cells failed to reach their biological potential but because of things we did not know in terms of grafting and supporting the grafted cells."

Gregoire Courtine, PhD, a Professor and investigator at the Center for Neuroprosthetics and at the Brain Mind Institute, both part of the Swiss Federal Institute of Technology (EPFL) in Geneva, also conducts research seeking to restore function after spinal cord injury. He underscored the importance of the new findings.

"Dr. Tuszynski and his collaborators overcame a number of methodological difficulties specific to primates to obtain this breakthrough," he said. "Direct translation of their work to humans would have failed, and yet too many studies are bypassing vital translational work in primate models that is necessary before human clinical trials."

Successfully growing and proliferating functional grafted stem cells in spinal cord injuries is hindered by a multitude of innate, biological challenges. For example, the region surrounding the injury site — the so-called extracellular matrix — inhibits growth in the same way that a superficial scar never resembles the original tissue in form or function. The injury site is abundant with inhibitory myelin proteins (used to make the insulating sheath around many nerve fibers) but lacks growth-promoting factors, such as neurotrophins, that would encourage regeneration of nerve cells' axons and synapses.

Previous work by Tuszynski and others have found solutions or work-arounds for many of these obstacles, reporting notable progress using rodent models. The new work involves the use of human spinal cord-derived neural progenitor cells (NPCs) — stem cells destined to become nerve cells in the central nervous system (CNS) — in rhesus monkeys, whose biology and physiology is much more similar to humans. Because the NPCs were derived from an 8-week-old human embryonic spinal cord, they possessed active growth programs that supported robust axon extension and appeared to be insensitive to inhibitors present in the adult CNS.

Two weeks after the initial injury (a period intended to represent the time required for an injured person to medically stabilise undergoing neural stem cell therapy), researchers grafted 20 million NPCs into the injury lesions in the monkeys, supported by a cocktail of growth factors and immune suppression drugs.

The work was done at the California National Primate Research Center at UC Davis. Most of the investigators are from UC campuses. "This highly complex translational project shows the value of collaborative research across UC campuses with unique facilities," said co-author Michael Beattie, PhD, professor and director of research at the Brain and Spinal Injury Center at UC San Francisco.

Over the next nine months, the grafts grew, expressing key neural markers and sending hundreds of thousands of axons — the fibers through which nerve cells conduct signals to other nerve cells — through the injury site to undamaged cells and tissue on the other side. Several months into the study, researchers noted that the monkeys began to display partial recovery of movement in their affected forelimbs.

Notably, the team documented regeneration of corticospinal axons, which are essential for voluntary movement in humans, into the lesion sites — the first such known documentation in a primate model.

Courtine at EPFL, who was not involved in the study, said the findings challenge decades of work on the mechanisms of regeneration failure and "definitely represent a landmark in regeneration medicine." Nonetheless, he noted that the degree of functional improvement remained limited. "It is not surprising given that the functional integration of new cells and connections into the operation of the nervous system would require time and specific rehabilitation procedures," he said.

"It's possible that given a longer period of observation, greater recovery may have occurred," said the study's first author, Ephron S. Rosenzweig, PhD, an assistant adjunct professor in Tuszynski's lab. "Axon regeneration, synapse formation, myelination — these all take time, and are critical for neural function. Grafts, and the new circuitry they were part of, were still maturing at the end of our observations, so it seems possible that recovery might have continued."

Tuszynski said work remains to be done before initiating human clinical trials,

including production of a candidate neural stem cell line from humans that meets requirements of the Food and Drug Administration, and additional studies of safety. His group also continues to explore ways to further enhance the growth, distance and functionality of the regenerated cells.

"We seem to have overcome some major barriers, including the inhibitory nature of adult myelin against axon growth," he said. "Our work has taught us that stem cells will take a long time to mature after transplantation to an injury site, and that patience will be required when moving to humans. Still, the growth we observe from these cells is remarkable — and unlike anything I thought possible even ten years ago. There is clearly significant potential here that we hope will benefit humans with spinal cord injury."

Common Wifi Can Detect Weapons, Bombs and Chemicals in Bags

Ordinary WiFi can easily detect weapons, bombs and explosive chemicals in bags at museums, stadiums, theme parks, schools and other public venues, according to a Rutgers University-New Brunswick-led study.

The researchers' suspicious object detection system is easy to set up, reduces security screening costs and avoids invading privacy such as when screeners open and inspect bags, backpacks and luggage. Traditional screening typically requires high staffing levels and costly specialized equipment.

"This could have a great impact in protecting the public from dangerous objects," said Yingying (Jennifer) Chen, study co-author and a professor in the Department of Electrical

and Computer Engineering in Rutgers-New Brunswick's School of Engineering. "There's a growing need for that now."

The peer-reviewed study received a best paper award at the 2018 IEEE Conference on Communications and Network Security on cybersecurity. The study — led by researchers at the Wireless Information Network Laboratory (WINLAB) in the School of Engineering — included engineers at Indiana University-Purdue University Indianapolis (IUPUI) and Binghamton University.

WiFi, or wireless, signals in most public places can penetrate bags to get the dimensions of dangerous metal objects and identify them, including weapons, aluminum cans, laptops and batteries for bombs. WiFi can also be used to estimate the volume of liquids such as water, acid, alcohol and other chemicals for explosives, according to the researchers.

This low-cost system requires a WiFi device with two to three antennas and can be integrated into existing WiFi networks. The system analyses what happens when wireless signals penetrate and bounce off objects and materials.

Experiments with 15 types of objects and six types of bags demonstrated detection accuracy rates of 99 per cent for dangerous objects, 98 per cent for metal and 95 per cent for liquid. For typical backpacks, the accuracy rate exceeds 95 per cent and drops to about 90 per cent when objects inside bags are wrapped, Chen said.

"In large public areas, it's hard to set up expensive screening infrastructure like what's in airports," Chen said. "Manpower is always needed to check bags and we wanted to

develop a complementary method to try to reduce manpower."

Next steps include trying to boost accuracy in identifying objects by imaging their shapes and estimating liquid volumes, she said.

Fake News Detector Algorithm Works Better Than a Human

An algorithm-based system that identifies telltale linguistic cues in fake news stories could provide news aggregator and social media sites like Google News with a new weapon in the fight against misinformation.

The University of Michigan researchers who developed the system have demonstrated that it is comparable to and sometimes better than humans at correctly identifying fake news stories.

In a recent study, it successfully found fakes up to 76 per cent of the time, compared to a human success rate of 70 per cent. In addition, their linguistic analysis approach could be used to identify fake news articles that are too new to be debunked by cross-referencing their facts with other stories.

RadaMihalcea, the U-M computer science and engineering professor behind the project, said an automated solution could be an important tool for sites that are struggling to deal with an onslaught of fake news stories, often created to generate clicks or to manipulate public opinion.

Catching fake stories before they have real consequences can be difficult, as aggregator and social media sites today rely heavily on human editors who often can't keep up with the influx of news. In addition, current debunking techniques often depend on

external verification of facts, which can be difficult with the newest stories. Often, by the time a story is proven a fake, the damage has already been done.

Linguistic analysis takes a different approach, analysing quantifiable attributes like grammatical structure, word choice, punctuation and complexity. It works faster than humans and it can be used with a variety of different news types.

"You can imagine any number of applications for this on the front or back end of a news or social media site," Mihalcea said. "It could provide users with an estimate of the trustworthiness of individual stories or a whole news site. Or it could be a first line of defense on the back end of a news site, flagging suspicious stories for further review. A 76 per cent success rate leaves a fairly large margin of error, but it can still provide valuable insight when it's used alongside humans."

Linguistic algorithms that analyse written speech are fairly common today, Mihalcea said. The challenge to building a fake news detector lies not in building the algorithm itself, but in finding the right data with which to train that algorithm.

Fake news appears and disappears quickly, which makes it difficult to collect. It also comes in many genres, further complicating the collection process. Satirical news, for example, is easy to collect, but its use of irony and absurdity make it less useful for training an algorithm to detect fake news that is meant to mislead.

Ultimately, Mihalcea's team created its own data, crowdsourcing an online team that reverse-engineered verified genuine news stories into fakes. This is how most actual

fake news is created, Mihalcea said, by individuals who quickly write them in return for a monetary reward.

Study participants, recruited with the help of Amazon Mechanical Turk, were paid to turn short, actual news stories into similar but fake news items, mimicking the journalistic style of the articles. At the end of the process, the research team had a dataset of 500 real and fake news stories.

They then fed these labeled pairs of stories to an algorithm that performed a linguistic analysis, teaching itself distinguish between real and fake news. Finally, the team turned the algorithms to a dataset of real and fake news pulled directly from the web, netting the 76 per cent success rate.

The details of the new system and the dataset that the team used to build it are freely available, and Mihalcea says they could be used by news sites or other entities to build their own fake news detection systems. She says that future systems could be further honed by incorporating metadata such as the links and comments associated with a given online news item.

A paper detailing the system will be presented on 24 August at the 27th International Conference on Computational Linguistics in Santa Fe, N.M. Mihalcea worked with U-M computer science and engineering assistant research scientist Veronica Perez-Rosas, psychology researcher Bennett Kleinberg at the University of Amsterdam and U-M undergraduate student Alexandra Lefevre.

Math with Good Posture Can Mean Better Scores, Study Suggests

Sitting up straight aids performance, researchers find

If you've ever felt like a deer in the headlights before taking a math test or speaking before a large group of people, you could benefit from a simple change in posture. As part of a new study by researchers at San Francisco State University, 125 college students were tested to see how well they could perform simple math — subtracting 7 from 843 sequentially for 15 seconds — while either slumped over or sitting up straight with shoulders back and relaxed. Fifty-six per cent of the students reported finding it easier to perform the math in the upright position.

"For people who are anxious about math, posture makes a giant difference," said Professor of Health Education Erik Peper. "The slumped-over position shuts them down and their brains do not work as well. They cannot think as clearly." Before the study began, students filled out an anonymous questionnaire asking them to rate their anxiety levels while taking exams and performing math; they also described any physical symptoms of stress they experienced during test taking.

According to co-author Associate Professor of Health Education Richard Harvey, slumping over is a defensive posture that can trigger old negative memories in the body and brain. While the students without math anxiety did not report as great a benefit from better posture, they did find that doing math while slumped over was somewhat more difficult.

Peper and Harvey say these findings about body position can help people prepare for many different types of performance under stress, not just math tests. Athletes, musicians and public speakers can all benefit from better posture prior to and during their performance. "You have a choice," said Peper. "It's about using an empowered position to optimise your focus."

That empowerment could be particularly helpful to students facing the challenge called "stereotype threat," said Lauren Mason, one of the paper's authors and a recent SF State graduate. A first-generation college student, Mason can identify with such students, who experience fear and insecurity because of a belief by others — which can become internalised — that they won't do as well at math. Mason said she has benefited personally from using a more empowered posture before taking difficult tests, including math. She believes that adopting a more confident posture could help other first-generation students as well as women entering science and math, who often battle stereotype threat, too.

"I always felt insecure about my math abilities even though I excelled at other subjects," said Mason, who helped design the experiment in the study. "You build a relationship with [math] so early — as early as elementary school. You can carry that negative self-talk throughout your life, impacting your perception of yourself."

Mason said the study results demonstrate a simple way to improve many aspects of life, especially when stress is involved: "The way we carry ourselves and interact in space influences not only how others perceive us but also how we perceive ourselves."

Printable Tags Turn Everyday Objects into Smart, Connected Devices

Engineers have developed printable metal tags that could be attached to everyday objects and turn them into 'smart' Internet of Things devices.

The metal tags are made from patterns of copper foil printed onto thin, flexible, paper-like substrates and are made to reflect WiFi signals. The tags work essentially like 'mirrors' that reflect radio signals from a WiFi router. When a user's finger touches these mirrors, it disturbs the reflected WiFi signals in such a way that can be remotely sensed by a WiFi receiver, like a smartphone.

The tags can be tacked onto plain objects that people touch and interact with every day, like water bottles, walls or doors. These plain objects then essentially become smart, connected devices that can signal a WiFi device whenever a user interacts with them. The tags can also be fashioned into thin keypads or smart home control panels that can be used to remotely operate WiFi-connected speakers, smart lights and other Internet of Things appliances.

"Our vision is to expand the Internet of Things to go beyond just connecting smartphones, smartwatches and other high-end devices," said senior author Xinyu Zhang, a professor of electrical and computer engineering at the UC San Diego Jacobs School of Engineering and member of the Center for Wireless Communications at UC San Diego. "We're developing low-cost, battery-free, chipless, printable sensors that can include everyday objects as part of the Internet of Things."

Zhang's team named the technology 'LiveTag.' These metal tags are designed to only reflect specific signals within in the WiFi frequency range. By changing the type of material they're made of and the pattern in which they're printed, the researchers can redesign the tags to reflect either Bluetooth, LTE or cellular signals.

The tags have no batteries, silicon chips, or any discrete electronic components, so they require hardly any maintenance — no batteries to change, no circuits to fix.

The team presented their work at the recent USENIX Symposium on Networked Systems Design and Implementation Conference.

Smart Tagging

As a proof of concept, the researchers used LiveTag to create a paper-thin music player controller complete with a play/pause button, next track button and sliding bar for tuning volume. The buttons and sliding bar each consist of at least one metal tag so touching any of them sends signals to a WiFi device. The researchers have so far only tested the LiveTag music player controller to remotely trigger a WiFi receiver, but they envision that it would be able to remotely control WiFi-connected music players or speakers when attached to a wall, couch armrest, clothes, or other ordinary surface.

The researchers also adapted LiveTag as a hydration monitor. They attached it to a plastic water bottle and showed that it could be used to track a user's water intake by monitoring the water level in the bottle. The water inside affects the tag's response in the same way a finger touch would — as long as the bottle is not made of metal, which would block the signal. The tag has multiple resonators that

each get detuned at a specific water level. The researchers imagine that the tag could be used to deliver reminders to a user's smartphone to prevent dehydration.

Future Applications

On a broader scope, Zhang envisions using LiveTag technology to track human interaction with everyday objects. For example, LiveTag could potentially be used as an inexpensive way to assess the recovery of patients who have suffered from stroke.

"When patients return home, they could use this technology to provide data on their motor activity based on how they interact with everyday objects at home — whether they are opening or closing doors in a normal way, or if they are able to pick up bottles of water, for example. The amount, intensity and frequency of their activities could be logged and sent to their doctors to evaluate their recovery," said Zhang. "And this can all be done in the comfort of their own homes rather than having to keep going back to the clinic for frequent motor activity testing," he added.

Another example is tagging products at retail stores and assessing customer interest based on which products they touch. Rather than use cameras, stores could use LiveTag as an alternative that offers customers more privacy, said Zhang.

Next Steps

The researchers note several limitations of the technology. LiveTag currently cannot work with a WiFi receiver further than one metre (three feet) away, so researchers are working on improving the tag sensitivity and detection range. Ultimately, the team aims to develop a way to make the tags using normal paper and

ink printing, which would make them cheaper to mass produce.

Paper title: "LiveTag: Sensing Human-Object Interaction through Passive Chipless WiFi Tags." Co-authors include ChuhanGao and Yilong Li at University of Wisconsin-Madison.

Artificial Synaptic Device Simulating the Function of Human Brain

A research team led by Director Myoung-Jae Lee from the Intelligent Devices and Systems Research Group at DGIST has succeeded in developing an artificial synaptic device that mimics the function of the nerve cells (neurons) and synapses that are response for memory in human brains.

Synapses are where axons and dendrites meet so that neurons in the human brain can send and receive nerve signals; there are known to be hundreds of trillions of synapses in the human brain.

This chemical synapse information transfer system, which transfers information from the brain, can handle high-level parallel arithmetic with very little energy, so research on artificial synaptic devices, which mimic the biological function of a synapse, is under way worldwide.

Dr. Lee's research team, through joint research with teams led by Professor Gyeong-Su Park from Seoul National University; Professor Sung Kyu Park from Chung-ang University; and Professor Hyunsang Hwang from POSTEC, developed a high-reliability artificial synaptic device with multiple values by structuring tantalum oxide — a trans-metallic material — into two layers of Ta_2O_{5-x} and TaO_{2-x} and by controlling its surface.

The artificial synaptic device developed by the research team is an electrical synaptic device that simulates the function of synapses in the brain as the resistance of the tantalum oxide layer gradually increases or decreases depending on the strength of the electric signals. It has succeeded in overcoming durability limitations of current devices by allowing current control only on one layer of Ta_2O_{5-x}.

In addition, the research team successfully implemented an experiment that realised synapse plasticity, which is the process of creating, storing, and deleting memories, such as long-term strengthening of memory and long-term suppression of memory deleting by adjusting the strength of the synapse connection between neurons.

The non-volatile multiple-value data storage method applied by the research team has the technological advantage of having a small area of an artificial synaptic device system, reducing circuit connection complexity, and reducing power consumption by more than one-thousandth compared to data storage methods based on digital signals using 0 and 1 such as volatile CMOS (Complementary Metal Oxide Semiconductor).

The high-reliability artificial synaptic device developed by the research team can be used in ultra-low-power devices or circuits for processing massive amounts of big data due to its capability of low-power parallel arithmetic. It is expected to be applied to next-generation intelligent semiconductor device technologies such as development of artificial intelligence (AI) including machine learning and deep learning and brain-mimicking semiconductors.

Dr. Lee said, "This research secured the reliability of existing artificial synaptic devices and improved the areas pointed out as disadvantages. We expect to contribute to the development of AI based on the neuromorphic system that mimics the human brain by creating a circuit that imitates the function of neurons."

Physicists Train Robotic Gliders to Soar Like Birds

The novel study applies reinforcement learning to set a course toward artificial intelligence

The words "fly like an eagle" are famously part of a song, but they may also be words that make some scientists scratch their heads. Especially when it comes to soaring birds like eagles, falcons and hawks, who seem to ascend to great heights over hills, canyons and mountain tops with ease. Scientists realise that upward currents of warm air assist the birds in their flight, but they don't know how the birds find and navigate these thermal plumes.

To figure it out, researchers from the University of California San Diego used reinforcement learning to train gliders to autonomously navigate atmospheric thermals, soaring to heights of 700 metres-nearly 2,300 feet. The novel research results, published in the 19 September issue of *Nature*, highlight the role of vertical wind accelerations and roll-wise torques as viable biological cues for soaring birds. The findings also provide a navigational strategy that directly applies to the development of autonomous soaring vehicles, or unmanned aerial vehicles (UAVs).

"This paper is an important step toward artificial intelligence—how to autonomously

soar in constantly shifting thermals like a bird. I was surprised that relatively little learning was needed to achieve expert performance," said Terry Sejnowski, a member of the research team from the Salk Institute for Biological Studies and UC San Diego's Division of Biological Sciences.

Reinforcement learning is an area of machine learning, inspired by behavioural psychology, whereby an agent learns how to behave in an environment based on performed actions and the results. According to UC San Diego Department of Physics Professor Massimo Vergassola and PhD candidate Gautam Reddy, it offers an appropriate framework to identify an effective navigational strategy as a sequence of decisions taken in response to environmental cues.

"We establish the validity of our learned flight policy through field experiments, numerical simulations and estimates of the noise in measurements that is unavoidably present due to atmospheric turbulence," explained Vergassola. "This is a novel instance of learning a navigational task in the field, where learning is severely challenged by a multitude of physical effects and the unpredictability of the natural environment."

In the study, conducted collaboratively with the UC San Diego Division of Biological Sciences, the Salk Institute and the Abdus Salam International Center for Theoretical Physics in Trieste, Italy, the team equipped two-metre wingspan gliders with a flight controller. The device enabled on-board implementation of autonomous flight policies via precise control over bank angle and pitch. A navigational strategy was determined solely from the gliders' pooled experiences collected over several days in the field using exploratory

behavioural strategies. The strategies relied on new on-board methods, developed in the course of the research, to accurately estimate the gliders' local vertical wind accelerations and the roll-wise torques, which served as navigational cues.

The scientists' methodology involved estimating the vertical wind acceleration, the vertical wind velocity gradients across the gliders' wings, designing the learning module, learning the thermalling strategy in the field, testing the performance of the learned policy in the field, testing the performance for different wingspans in simulations and estimating the noise in gradient sensing due to atmospheric turbulence.

"Our results highlight the role of vertical wind accelerations and roll-wise torques as viable biological mechanosensory cues for soaring birds, and provide a navigational strategy that is directly applicable to the development of autonomous soaring vehicles," said Vergassola.

NASA Learns More About Interstellar Visitor ʻOumuamua

In November 2017, scientists pointed NASA's Spitzer Space Telescope toward the object known as ʻOumuamua — the first known interstellar object to visit our solar system. The infrared Spitzer was one of many telescopes pointed at ʻOumuamua in the weeks after its discovery that October. ʻOumuamua was too faint for Spitzer to detect when it looked more than two months after the object's closest aproach to earth in early September. However, the "non-detection" puts a new limit on how large the strange object can be. The results are reported in

a new study published in the *Astronomical Journal* and coauthored by scientists at NASA's Jet Propulsion Laboratory in Pasadena, California.

The new size limit is consistent with the findings of a research paper published earlier this year, which suggested that outgassing was responsible for the slight changes in 'Oumuamua's speed and direction as it was tracked last year: The authors of that paper conclude the expelled gas acted like a small thruster gently pushing the object. That determination was dependent on 'Oumuamua being relatively smaller than typical solar system comets. (The conclusion that 'Oumuamua experienced outgassing suggested that it was composed of frozen gases, similar to a comet.)

"'Oumuamua has been full of surprises from day one, so we were eager to see what Spitzer might show," said David Trilling, lead author on the new study and a professor of astronomy at Northern Arizona University. "The fact that 'Oumuamua was too small for Spitzer to detect is actually a very valuable result."

'Oumuamua was first detected by the University of Hawaii's Pan-STARRS 1 telescope on Haleakala, Hawaii (the object's name is a Hawaiian word meaning "visitor from afar arriving first"), in October 2017 while the telescope was surveying for near-earth asteroids.

Subsequent detailed observations conducted by multiple ground-based telescopes and NASA's Hubble Space Telescope detected the sunlight reflected off 'Oumuamua's surface. Large variations in the object's brightness suggested that 'Oumuamua is highly elongated and probably less than half a mile (2,600 feet, or 800 metres) in its longest dimension.

But Spitzer tracks asteroids and comets using the infrared energy, or heat, that they radiate, which can provide more specific information about an object's size than optical observations of reflected sunlight alone would.

The fact that 'Oumuamua was too faint for Spitzer to detect sets a limit on the object's total surface area. However, since the non-detection can't be used to infer shape, the size limits are presented as what 'Oumuamua's diameter would be if it were spherical. Using three separate models that make slightly different assumptions about the object's composition, Spitzer's non-detection limited 'Oumuamua's "spherical diameter" to 1,440 feet (440 metres), 460 feet (140 metres) or perhaps as little as 320 feet (100 metres). The wide range of results stems from the assumptions about 'Oumuamua's composition, which influences how visible (or faint) it would appear to Spitzer were it a particular size.

Small but Reflective

The new study also suggests that 'Oumuamua may be up to 10 times more reflective than the comets that reside in our solar system — a surprising result, according to the paper's authors. Because infrared light is largely heat radiation produced by 'warm' objects, it can be used to determine the temperature of a comet or asteroid; in turn, this can be used to determine the reflectivity of the object's surface — what scientists call albedo. Just as a dark T-shirt in sunlight heats up more quickly than a light one, an object with low reflectivity retains more heat than an object with high reflectivity. So a lower temperature means a higher albedo.

A comet's albedo can change throughout its lifetime. When it passes close to the sun, a comet's ice warms and turns directly into a gas, sweeping dust and dirt off the comet's surface and revealing more reflective ice.

'Oumuamua had been travelling through interstellar space for millions of years, far from any star that could refresh its surface. But it may have had its surface refreshed through such 'outgassing' when it made an extremely close approach to our sun, a little more than five weeks before it was discovered. In addition to sweeping away dust and dirt, some of the released gas may have covered the surface of 'Oumuamua with a reflective coat of ice and snow — a phenomenon that's also been observed in comets in our solar system.

'Oumuamua is on its way out of our solar system — almost as far from the sun as Saturn's orbit — and is well beyond the reach of any existing telescopes.

"Usually, if we get a measurement from a comet that's kind of weird, we go back and measure it again until we understand what we're seeing," said Davide Farnocchia, of the Center for Near Earth Object Studies (CNEOS) at JPL and a coauthor on both papers. "But this one is gone forever; we probably know as much about it as we're ever going to know."

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space Systems Company in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

Artificial Intelligence Controls Quantum Computers

Neural networks enable learning of error correction strategies for computers based on quantum physics

Quantum computers could solve complex tasks that are beyond the capabilities of conventional computers. However, the quantum states are extremely sensitive to constant interference from their environment. The plan is to combat this using active protection based on quantum error correction. Florian Marquardt, Director at the Max Planck Institute for the Science of Light, and his team have now presented a quantum error correction system that is capable of learning thanks to artificial intelligence.

In 2016, the computer program AlphaGo won four out of five games of Go against the world's best human player. Given that a game of Go has more combinations of moves than there are estimated to be atoms in the universe, this required more than just sheer processing power. Rather, AlphaGo used artificial neural networks, which can recognise visual patterns and are even capable of learning. Unlike a human, the program was able to practise hundreds of thousands of games in a short time, eventually surpassing the best human player. Now, the Erlangen-based researchers are using neural networks of this kind to develop error-correction learning for a quantum computer.

Artificial neural networks are computer programs that mimic the behaviour of interconnected nerve cells (neurons) — in the case of the research in Erlangen, around two thousand artificial neurons are

connected with one another. "We take the latest ideas from computer science and apply them to physical systems," explains Florian Marquardt. "By doing so, we profit from rapid progress in the area of artificial intelligence."

Artificial Neural Networks Could Outstrip Other Error-correction Strategies

The first area of application is quantum computers, as shown by the recent paper, which includes a significant contribution by Thomas Fösel, a doctoral student at the Max Planck Institute in Erlangen. In the paper, the team demonstrates that artificial neural networks with an AlphaGo-inspired architecture are capable of learning — for themselves — how to perform a task that will be essential for the operation of future quantum computers: quantum error correction. There is even the prospect that, with sufficient training, this approach will outstrip other error-correction strategies.

To understand what it involves, you need to look at the way quantum computers work. The basis for quantum information is the quantum bit, or qubit. Unlike conventional digital bits, a qubit can adopt not only the two states zero and one, but also superpositions of both states. In a quantum computer's processor, there are even multiple qubits superimposed as part of a joint state. This entanglement explains the tremendous processing power of quantum computers when it comes to solving certain complex tasks at which conventional computers are doomed to fail. The downside is that quantum information is highly sensitive to noise from its environment. This and other peculiarities of the quantum world mean that quantum information needs regular repairs

— that is, quantum error correction. However, the operations that this requires are not only complex but must also leave the quantum information itself intact.

Quantum Error-correction is Like a Game of *Go* with Strange Rules

"You can imagine the elements of a quantum computer as being just like a Go board," says Marquardt, getting to the core idea behind his project. The qubits are distributed across the board like pieces. However, there are certain key differences from a conventional game of Go: all the pieces are already distributed around the board, and each of them is white on one side and black on the other. One colour corresponds to the state zero, the other to one, and a move in a game of quantum Go involves turning pieces over. According to the rules of the quantum world, the pieces can also adopt grey mixed colours, which represent the superposition and entanglement of quantum states.

When it comes to playing the game, a player — we'll call her Alice — makes moves that are intended to preserve a pattern representing a certain quantum state. These are the quantum error correction operations. In the meantime, her opponent does everything they can to destroy the pattern. This represents the constant noise from the plethora of interference that real qubits experience from their environment. In addition, a game of quantum Go is made especially difficult by a peculiar quantum rule: Alice is not allowed to look at the board during the game. Any glimpse that reveals the state of the qubit pieces to her destroys the sensitive quantum state that the game is currently occupying. The question is: how can she make the right moves despite this?

Auxiliary Qubits Reveal Defects in the Quantum Computer

In quantum computers, this problem is solved by positioning additional qubits between the qubits that store the actual quantum information. Occasional measurements can be taken to monitor the state of these auxiliary qubits, allowing the quantum computer's controller to identify where faults lie and to perform correction operations on the information-carrying qubits in those areas. In our game of quantum Go, the auxiliary qubits would be represented by additional pieces distributed between the actual game pieces. Alice is allowed to look occasionally, but only at these auxiliary pieces.

In the Erlangen researchers' work, Alice's role is performed by artificial neural networks. The idea is that, through training, the networks will become so good at this role that they can even outstrip correction strategies devised by intelligent human minds. However, when the team studied an example involving five simulated qubits, a number that is still manageable for conventional computers, they were able to show that one artificial neural network alone is not enough. As the network can only gather small amounts of information about the state of the quantum bits, or rather the game of quantum Go, it never gets beyond the stage of random trial and error. Ultimately, these attempts destroy the quantum state instead of restoring it.

One neural network uses its prior knowledge to train another

The solution comes in the form of an additional neural network that acts as a teacher to the first network. With its prior knowledge of the quantum computer that is to be controlled, this teacher network

is able to train the other network — its student — and thus to guide its attempts towards successful quantum correction. First, however, the teacher network itself needs to learn enough about the quantum computer or the component of it that is to be controlled.

In principle, artificial neural networks are trained using a reward system, just like their natural models. The actual reward is provided for successfully restoring the original quantum state by quantum error correction. "However, if only the achievement of this long-term aim gave a reward, it would come at too late a stage in the numerous correction attempts," Marquardt explains. The Erlangen-based researchers have therefore developed a reward system that, even at the training stage, incentivises the teacher neural network to adopt a promising strategy. In the game of quantum Go, this reward system would provide Alice with an indication of the general state of the game at a given time without giving away the details.

The Student Network Can Surpass Its Teacher through Its Own Actions

"Our first aim was for the teacher network to learn to perform successful quantum error correction operations without further human assistance," says Marquardt. Unlike the school student network, the teacher network can do this based not only on measurement results but also on the overall quantum state of the computer. The student network trained by the teacher network will then be equally good at first, but can become even better through its own actions.

In addition to error correction in quantum computers, Florian Marquardt envisages other applications for artificial intelligence.

In his opinion, physics offers many systems that could benefit from the use of pattern recognition by artificial neural networks.

First Detection of Rain over the Ocean by Navigation Satellites

In order to analyse climate change or provide information on natural hazards, for example, it is important for researchers to gather knowledge about rain. Better knowledge of precipitation and its distribution could, for example, help protect against river flooding. On land, monitoring stations can provide data by collecting precipitation. At sea, it is not so easy.

A new approach by a team around *Milad Asgarimehr,* who works in the GFZ section for Space Geodetic Techniques and at the Technical University of Berlin, together with researchers from the Earth System Research Laboratory of the National Oceanic and Atmospheric Administration of the USA (NOAA) and the University of Potsdam, uses information contained in radar signals from GNSS satellites (Global Navigation Satellite System) to detect rain over the sea. The technology is called GNSS Reflectometry. It is an innovative satellite remote sensing method with a broad spectrum of geophysical applications. As garimehr and his colleagues have now published their results in the journal *Geophysical Research Letters.*

According to the researchers, the new approach could help to monitor atmospheric precipitation better than before. Asgarimehr: "Our research can serve as a starting point for the development of an additional rain indicator. We can provide precipitation information using GNSS Reflectometry with unprecedented temporal resolution and spatial coverage."

"GNSS are 'all-weather navigation systems'," explains Asgarimehr. "A long-held basic assumption was therefore that their signals are composed in such a way that they are not noticeably attenuated by clouds or typical precipitation in the atmosphere and therefore cannot detect precipitation." The new study therefore uses a different effect to detect rain over the sea: The roughness of the sea surface.

GNSS Reflectometry Can Measure Sea Surface Roughness

That surface is 'rough' mainly because winds create waves on it. The strength of the satellite signals reflected by the surface is inversely proportional to their roughness: the more and the stronger the waves, the weaker the reflected signal. Recently, researchers were able to prove that it is possible to determine the wind speed over the oceans from measurements of the roughness of its surface.

Raindrops falling on a sea surface also change its roughness. Milad Asgarimehr and the team around him asked themselves: "Can GNSS Reflectometry detect precipitation over oceans?" This is also the title of their recently published study. If the answer is yes, GNSS Reflectometry satellites could detect rain almost like an observer watching raindrops disturb the mirror image of the moon on the surface of a lake at night. However, there is one major difference: unlike moonlight, GNSS signals are able to penetrate the clouds.

A New Theoretical Model Comes to the Rescue

During the analysis of data from the navigation satellite TDS-1 (TechDemoSat-1), Asgarimehr found evidence that rain is

detectable over the oceans if the winds are not too strong. However, his research still lacked a theoretical foundation. "For a long time it was thought that GNSS Reflectometry measurements should be insensitive to the small-scale surface roughness caused by raindrops on the sea surface," explains Asgarimehr. But the publication of a new theoretical model in 2017 provided a plausible estimate of the physics of the scattering of radar signals on a sea surface disturbed by weak winds.

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