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Where Medical Technology and Astrophysics Meet

At the University of Bern, astrophysicists of the Center for Space and Habitability (CSH) teamed up with medical technology researchers to develop a new method to analyse spectra of atmospheres of planets beyond our solar system. The unusual collaboration applied an artificial intelligence tool to study the chemistry of exoplanetary atmospheres.

When Kevin Heng, director of the CSH, met Raphael Sznitman, Professor at the ARTORG Center for Biomedical Engineering Research, the astrophysicist was immediately fascinated by the work of the medical technology researcher using AI, short for artificial intelligence. Machine learning is a branch of artificial intelligence, a buzzword in today's science and technology world that gives computers the ability to learn from data without being explicitly programmed. Sznitman and his group are using machine learning in particular to control surgical tools during operations on the eye and detect biomarkers for disease identification from images. Revolutionising many fields of science, machine learning is also becoming ubiquitous in astronomy, but it is not yet used in Heng's specialist field, the atmospheres of exoplanets.

"The way Raphael Sznitman and his team look at images is very similar to the way astronomers are analysing images and we even speak roughly the same technical language," Kevin Heng states: "Whether in astronomy or medical technology, we always try to understand the flaws of imaging technologies and improve them." Raphael Sznitman explains: "In my group we develop analytical methods that can be applied to different types of data." So, the two scientists decided to start a very unusual interdisciplinary collaboration and attempted for the first time to apply machine learning as a superior pattern recognition tool to analyse exoplanetary atmospheres. The resulting paper has now been published in the journal *Nature Astronomy*.

The choice between pragmatism and realism

In astronomy, light from an object is taken and split in the different colours to get a spectrum. The spectrum of an exoplanet contains hidden information about the molecules present in its atmosphere, the physical conditions and the amount of clouds. Analysing and interpreting the spectrum the astronomer can for instance find water in a planet's atmosphere and determine its habitability. The current standard approach is to search among a large family of model spectra that

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best fits the data from the exoplanet, which is a very time-consuming process and leaves room for human misjudgement. "By necessity, we always had to compromise between being feasible and making the model as realistic as possible," Heng explains: "Everything was done as a compromise between pragmatism and realism."

With the help of Postdoc Pablo Marquez-Neila (ARTORG) and PhD student Chloe Fisher (CSH), the four-person team developed a new technique to simplify the approach. They devised a way to compute a large grid of models, and then use it as a training set for the machine learning procedure. With the help of this data, the computer learns to determine the composition of the exoplanetary atmosphere from a spectrum. The method with which the computer finds the optimum model is called "random forest". It is a supervised form of machine learning which is traditionally used to classify objects in images and basically works like the face recognition we know from our smartphones. "Based on the data the computer learns whether a particular object is present in an image or not. Since the process consists of many such decision trees, it is called random forest," explains Raphael Sznitman. "We had to sit altogether several times until we fully understood the problem," he remembers: "Then, it was clear to us that random forests can also be applied to light spectra and would do the trick." Heng recalls: "I remember that moment when Raphael simply said, 'random forest.' I was intrigued, although in the end it took me several weeks to even conceptually understand what it meant. But what Raphael immediately saw, with his experience in medical image analysis, was that this method could do the job."

To demonstrate the method the astrophysicists picked as an example the exoplanet WASP-12b, a Jupiter-sized planet with a temperature of more than 1000 degree Celsius. The computer had to look for patterns in the observed spectrum. "The human eye is very good at recognising faces with intuitive pattern recognition," explains Heng: "But when it comes to very abstract patterns in a multi-dimensional space our human mind struggles to do that." The computer succeeded in the case of the hot Jupiter WASP-12b and demonstrated that the "random forest" method worked much faster than the regular approach without machine learning.

Better observing proposals

To Heng, this new approach is an opportunity to combine the best of human intuition with the possibilities offered by machine learning. "This novel adaptation of machine learning opens up several exciting avenues for future work. We now have better information, when it comes to constraining, say, the abundance of water in an exoplanetary atmosphere," says Heng: "This increases our chances in the international competition for valuable telescope time and perhaps even influence the design of future instruments."

"The computer and I even had a little competition on which data points were the most important for constraining a given parameter. When my physical intuition got it right, the computer got it right too. When my intuition faltered, the computer still got it right. It was quite depressing," Heng remarked. "What is exciting as well is that it democratises the analysis of spectra, because anyone with a laptop running the Python software can do what we did in the span of a coffee break. We intend to make our software publicly available."

Interdisciplinarity benefits everyone involved

The collaboration will continue and should also help to solve medical problems. Astronomy has a long tradition of imaging instruments and dealing with problems using models. "Medical images of patients can be less than ideal, because, for example, the scanners are sometimes not optimal, not powerful enough or not perfectly able to capture the body part in question," says Raphael Sznitman: "The astronomers' great experience with modelling is also very interesting for image processing in medicine and could improve the way patients receive their diagnosis and care."

The cooperation between astrophysicists and medical technology researchers is a good example for interdisciplinarity which benefits all involved. "Interdisciplinarity is becoming increasingly important. When working with researchers from other disciplines, you have to learn to make yourself understandable. This communicative way of science is very enriching," says Kevin Heng. PhD student Chloe Fisher remembers: "It was incredibly interesting to see how computer scientists approach problems and develop ideas differently." Surprisingly, some of the main concerns the astrophysicists had about the method had trivial solutions in the computer science field, and other issues arose where they did not expect them at all. "It was a real example of bridging the gap between our two fields," the astrophysicist summarizes.

Publication details:

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