Neural networks show potential for identifying gamma rays detected by the Cherenkov telescope array

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A prototype of a CTA telescope at La Palma. Credit: Flickr/CTAO

With the Cherenkov Telescope Array (CTA) that is currently under construction, researchers hope to observe highly energetic gamma rays

that could lead to the discovery of new objects in and outside of our galaxy and even unravel the mystery of dark matter. However, identifying these gamma rays is not easy. Researchers from the CTA consortium are now trying to perfect it with neural networks trained on the Piz Daint supercomputer.

Upon completion in 2025, the Cherenkov Telescope Array (CTA) will be the largest gamma-ray observation telescope array ever built. More than 100 telescopes with diameters between 4 and 23 meters are being installed in the northern and southern hemispheres, at the Roque de los Muchachos Observatory on the Canary Island La Palma and in the Atacama Desert in Chile. The telescopes are designed to comprehensively record flashes of light induced by the gamma rays traveling through the cosmos that strike the Earth's atmosphere. Gamma rays originate from violent cosmic events and are a trillion times more energetic than visible light. They are generated by so-called "cosmic particle accelerators" such as supernova explosions or supermassive black holes devouring surrounding stars, gas and dust.

Extracting gamma rays from particle shower poses challenge

When gamma rays hit the Earth's atmosphere, they interact with the atoms and molecules of the air to create a particle shower, which mostly produces blue flashes of light called Cherenkov light. This light is collected by the specially designed telescope's mirror system and focused to extremely fast cameras. With this data, researchers can draw conclusions about the source of the gamma rays that could make it possible to discover hundreds of new objects in our own galaxy, the Milky Way, and even in star-forming galaxies and supermassive black holes outside of it. The gamma rays detected by CTA could, among other things, also provide a direct signature of dark matter, the existence

of which is supported by indirect observations but has never been observed directly.

The photos of these cosmic events collected by the CTA show elongated ellipses, according to Etienne Lyard and his colleagues from the Département d'Astronomie, Université de Genève, in their latest study published in the *Journal of Physics: Conference Series*. There are two kind of particles causing these events: hadrons, which are the most numerous; and the particles of interest, the high-energy photons called gamma rays. "Researchers are mostly interested in the gamma rays, since they traverse the interstellar space in a straight line, while hadrons, being charged particles, bend due to magnetic fields," Lyard says.

There are well established procedures for differentiating between gamma rays and hadrons; but in order to be as certain as possible that only gamma rays are detected and evaluated, a great deal of ambiguous events are filtered out, which reduces the overall sensitivity of the instruments. Nevertheless, sometimes hadron events are still falsely identified as gamma rays, which then contaminate the experiment as background noise.

Neural networks improve sensitivity of telescope array

To improve the discrimination procedure between hadrons and gamma rays, and thus the sensitivity of the observatories, Lyard and his team have now attempted to distinguish them from each other using deep convolutional neural networks (CNNs) trained on the CSCS supercomputer Piz Daint. They evaluated the performance of the CNNs in comparison with conventional methods for detecting gamma rays (Boosted Decision Trees) by using events generated with Monte Carlo simulations, which, according to the authors, came closest to the real

events. "Our work is an attempt to use neural networks from computer vision, a kind of machine vision, that processes and analyzes the images captured by cameras in a variety of ways and adapts them to work on our data," says Lyard. And it turns out that, under specific conditions, the CNNs do outperform classical techniques.

Although there is still much room for improvement in the CNNs architecture, the researchers are convinced that these and other machine learning approaches could help get the best scientific output from the CTA observatory. "We are confident that these approaches will eventually become the norm, because it already outperforms state-of-the art techniques while no information about the physical processes at work was put in the analysis at all," Lyard says. "As our understanding of CNNs grows, more appropriate criterions—like time development of the elongated ellipses—will be used to perform the analysis, and the overall performance will certainly improve, too."

More information: M. Tracolli et al. Using DODAS as deployment manager for smart caching of CMS data management system, *Journal of Physics: Conference Series* (2020). DOI: 10.1088/1742-6596/1525/1/012084

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