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Enhanced classification and reconstruction of single-line events in the ANTARES neutrino telescope using deep neural networks endowed with Transfer Learning

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The ANTARES neutrino telescope stopped gathering data in February 2022,
after nearly 16 years of operation. The detector consisted of 12 vertical lines forming a 3D array of photosensors, which instrumented about 10 megatons of Mediterranean seawater. We present a method using Deep Learning that improves the direction reconstruction of single-line events, for which the reconstruction of the azimuth angle of the incoming neutrino is particularly difficult. We are able to improve by a factor of two the resolution of the zenithal angle with respect to previous standard reconstruction techniques, and we give a first estimation of the azimuthal angle, which was previously missing.

We complete this direction reconstruction with an event classifier and an energy estimator for single-line events, developed using novel combinations of different machine learning techniques. To estimate the energy of the neutrino candidate, a Principal Component Analysis (PCA) is applied to the activations of pre-trained direction neural networks. These new components are used as inputs for a new network. The event classifier is trained applying Transfer Learning, since the first layers are the convolutional part of the direction networks. This implementation has shown better results than training from scratch. We are able to differentiate neutrinos inducing a muon (with a long track) from that inducing a cascade shower with an overall accuracy of around 80% and a precision of 84% for tracks and 77% for showers.

The improvements are highly relevant for low-energy neutrino studies. Point source multimessenger searches have been tested using these new techniques, allowing to extend the sensitivities to low neutrino energies. They are also being applied to a dark matter search towards the direction of the Sun, where a better sensitivitity compared to published analyses is expected for WIMP candidates with mass below 150 GeV.

Poster prize

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