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Boosting the Resolution of the CTAO with Hybrid Machine-learning Maximum-likelihood Event Reconstruction

Gamma-ray measurements using the imaging atmospheric Cherenkov technique currently achieve the highest angular resolution in astronomy at very high energies, reaching down to arcminute scales at multi-TeV energies. High-resolution measurements provide the key to progress on many of the central questions in high-energy astrophysics, including the sites and mechanisms of particle acceleration up to PeV energies. The huge potential of the next-generation Cherenkov Telescope Array Observatory (CTAO) in this regard can be maximized with the help of improved algorithms for the reconstruction of the air-shower direction and energy.

Here, we present the FreePACT algorithm, a hybrid machine-learning maximum-likelihood reconstruction method for imaging atmospheric Cherenkov telescopes. It employs the neural ratio estimation technique from the field of likelihood-free inference to replace the analytical likelihood used in traditional image-likelihood fitting by a neural network that approximates the charge probability density function for each pixel in the camera.

The significant performance improvements provided by this algorithm are demonstrated using simulations of the planned CTAO southern array. We also discuss implications of the improved angular resolution for the science potential of CTAO using as an example the study of compact X-ray Pulsar Wind Nebulae.

Collaboration(s)

CTAO

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