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Generation of Air Shower Images for Imaging Air Cherenkov Telescopes using Diffusion Models

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The major goal of Imaging Atmospheric Cherenkov Telescopes (IACTs) is the investigation of gamma-ray sources through the detection of their induced air showers. For every detected gamma ray, there are up to 10000 cosmic ray protons present forming the background, which also needs to be studied. For a detailed understanding of the instrument for deriving its response to both gamma rays and protons, a significant number of simulations are required. These simulations are computationally extensive and time extensive, particularly for the simulation of proton-induced showers as their structure is of a more complex nature. Additionally, changes in the observation conditions also result in the need for new simulations. Thus, novel approaches to increase the efficiency and accelerate the shower simulations offer new prospects for astroparticle physics. Diffusion models have been established as the state of the art over the last years and demonstrated their effectiveness in fast event generation. In this work, we apply a score-based diffusion model to investigate the fast generation of IACT images using simulations of the High Energy Stereoscopic System (H.E.S.S.). The IACT camera features the FlashCam design, foreseen for the Cherenkov Telescope Array (CTA), with over 1500 pixels. The successful application of this machine learning model is verified through the analysis of several high- and low-level parameters that give information about the image and air shower properties. Furthermore, we compared the generated images of diffusion models to generative adversarial networks and found promising performance for the fast generation of IACT images.

Track

Astrophysics

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