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Towards the Increase in Granularity for the Main Hadronic ATLAS Calorimeter: Exploiting Deep Learning Methods

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An extensive upgrade programme has been developed for LHC and its experiments, which is crucial to allow the complete exploitation of the extremely high-luminosity collision data. The programme is staggered in two phases, so that the main interventions are foreseen in Phase II.
For this second phase, the main hadronic calorimeter of ATLAS (TileCal) will redesign its readout electronics but the optical signal pathway will be kept unchanged.
However, there is a technical possibility to increase the detector granularity, without changing its mechanical structure, by modifying only the calorimeter readout. During the high luminosity regime, particle jets with high transverse momentum tend to deposit its energy in the last layers of TileCal. Therefore, dividing the actual calorimeter cells into new subregions will improve momentum reconstruction, mass, transverse energy and angular position of those jets, allowing future analysis benefit from a finer-grained granularity detector.
The light emitted by the calorimeter tiles is collected by a set of WLS fibers grouped in a bundle, one per calorimeter cell, coupled by a light mixer to a Photomultiplier Tube (PMT).
Aiming at extracting additional information on the spatial distribution of the energy deposited within each cell, the original PMT is substituted by a Multi-Anode Photomultiplier
Tube (MA-PMT) with 64 photosensors distributed in a grid of 8 x 8 pixels. This makes it possible to increase the detector granularity by means of an algorithm whose purpose is to match the image pattern formed in the grid of pixels to a topological subregion within a given cell. Calibration data are used for algorithm development, which is costly to produce, demanding time and man power. Therefore, the Generative Adversarial Network (GAN) is used to simulate the interaction of particles in a calorimeter cell, and, thereafter, leveraging the amount of statistics for the final classification model development.
Using a variant of the GAN model based on deep layers (DCGAN), a substantial increase in the number of images was obtained. As a consequence, a supervised deep learning approach based on Convolutional Neural Network (CNN) could be developed for mapping the signal image information onto two regions of the 8 x 8 grid. During the development
stage, the synthetic images produced with the generative model were used to train the CNN and its performance was evaluated in real calibration data. The preliminary results show an accuracy of more than 95% in both splits. This is encouraging for a possible solution of a such important step in calorimeter upgrade in the ATLAS experiment.

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