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Convolutional neural networks demultiplexing in large Micromegas detectors for muography purposes

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The muography project at CEA/IRFU uses high precision large gaseous detectors known as multiplexed Micromegas [1] which aim to reduce the cost of the electronic part by accumulating signal amplitudes together from 1037 strips into only 61 channels. Thanks to the properties of this genetic multiplexing [2], conventional algorithms may be and have been developed to recover estimated signals afterwards, and make it possible to compute the position of incident muons on the detectors. However, those algorithms shall anticipate a lot of different cases (channel cross-talk, cut or dead strips on the detector, large angle or simultaneous particles, ⋯) and therefore suffer from several biases that limit the muography and tomography quality. Besides, some demultiplexing algorithms have been able to achieve good performances but are not time-effective enough or rely on geometrical assumptions that do not apply on all events [3]. After the demultiplexing process, we reconstruct the tracks of particles crossing multiple detectors. Unfortunately, in some cases, a few wrong tracks may ruin the signal to noise ratio and make it impossible to run some analysis (like 3D reconstructions from outside the Khufu's Pyramid).

The difficulty to write a demultiplexing algorithm and the motivation to correct the known biases motivated us to consider machine learning techniques as an option. Thus, our goal is to develop a model capable of splitting the 61 multiplexed amplitudes into estimations of the unknown 1037 physical signals before the multiplexing. That model should be able to run on an embedded Linux on the muon telescope itself.

In this ongoing work we are studying convolutional neural network to benefit from the spatial properties of the filtering process with as few parameters as possible. In particular we construct multiple layers of one-dimensional convolutions [4] to process the multiplexed signal using the typical abstracted structures in the data. Moreover, we try to embed the knowledge of the genetic multiplexing architecture into the network using custom layers constraining the intermediate or final values. For the training of the model we mainly benefit of simulations to avoid the biases of previous demultiplexing algorithms that are mandatory to get real data. Therefore, part of our work focuses on finding a training process that uses a well-chosen share of standard and rare events, in order to have the best possible generalization on real data. The preliminary results already show a higher purity (~15% less unlikely tracks) but a smaller efficiency (~5% less tracks) than the previous solution. With our latest progresses we expect to be able to produce a significantly better demultiplexing process, which will make it possible to re-analyze without prior knowledge the data that was taken on ScanPyramids and on nuclear reactors at CEA.

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