



Contribution ID: 134

Type: **Flashtalk with Poster**

A fast convolutional neural network for online particle track recognition

Wednesday, 1 May 2024 16:06 (3 minutes)

Timepix4 is a hybrid pixel detector readout ASIC developed by the Medipix4 Collaboration at CERN. It consists of a matrix of about 230k pixels, each equipped with amplifier, discriminator and time-to-digital converter with 195 ps bin size that allows to measure both time-of-arrival and time-over-threshold of the hits. Due to its characteristics, it can be exploited in a wide range of fields, such as fundamental physics, medical imaging or dosimetry, and can be coupled to different kind of sensors.

Timepix4 can produce up to 160 Gbps of output data, so, regardless of its application, a strong software counterpart is needed for fast and efficient data processing. Beyond the data acquisition and control software, we developed a fast convolutional neural network to recognize and label different types of radiation that interact with a silicon pixel sensor bump-bonded to the Timepix4. This neural network is trained for the time being exposing the detector to natural radioactivity and allows classification of the deposited energy pattern of each track to an electron, muon, photon or alpha particle.

The network has four different *convolutional* layers, with different kernel size, that work in parallel. Depending on the shape and number of pixels of the clusters, one or more layers can detect different features in the track. A *maximum* layer then merges the four outputs, so that the relevant features captured by the different layers are combined together and a final *dense* layer can correctly classify the input.

The neural network was implemented in Python3, using the Tensorflow v2 module, and it ran on a CPU Intel i7-3770 @ 3.40GHz. The training has been carried out on a 2000-tracks dataset for 150 epochs, taking a total time of 10 minutes. After the 150-epochs training, the network shows an accuracy of more than 95% and a loss < 0.2 and it can analyse more than 1600 tracks per second.

Given the reduced training time, this network can be adapted and re-trained to other tracks datasets, depending on the need: for example, it can be adapted for different radiation fields or for a different sensor coupled to the Timepix4, such as other semiconductors or microchannel plates.

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Session Classification: 4.1 Pattern recognition, Image analysis & Uncertainty quantification

Track Classification: Session B