Contribution ID: **298** Type: **Oral**

2D and 3D analysis improvements with Machine Learning for Muography Applications

Tuesday, 28 May 2024 15:50 (20 minutes)

Transmission muography is a non-invasive and non-destructive imaging method which allows to estimate the integrated density of a volume in a given direction (also referred as opacity). It is used in multiple societal applications like archaeology, nuclear safety and geoscience. It relies on the reconstruction of muon tracks that crossed the studied volume compared to the corresponding open sky expectation. The portable experimental setups developed by CEA/Irfu group operates four Micromegas gaseous detectors, HV and DAQ modules, and an embedded computer allowing remote control.
Used Micromegas detectors have a multiplexed readout to optimize the DAQ system, while keeping good spatial resolution (<1mm). However the natural muon flux is relatively low, so muography images can be really noisy and this statistical noise is propagated in the reconstructed 3D images. For this reason, we propose three new methods, using machine learning, which increase significantly the quality of 2D images and 3D reconstructions.
Firstly, we developed a new demultiplexing method for the Micromegas. It showed its efficiency both for 1D (0.11° resolution) and 2D (15° resolution) multiplexed detectors, the former operating in a hodoscopic tracker while the latter integrated in a Time Projection Chamber (TPC). We also showed that this method could differentiate (~99%) muons from electrons in the TPC.
Secondly, we demonstrated how diffusion models could denoise muography images. For this purpose we used data augmentation to model a few hundreds fake nuclear reactors. With such data we simulated muographies from different points of view and trained a neural network to denoise them.
These new methods significantly improved the muography images. Nonetheless, the used 3D reconstruction algorithm (SART) still has some limitations (artifacts, blurring, border effects…). We demonstrated that it was possible to build a 3D post-process neural network following the UNet architecture, which was trained to compensate SART's limitations.

Collaboration

Role of Submitter

I am the presenter

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Session Classification: Applications to Industrial and Societal Challenges - Oral session

Track Classification: T5 - Applications to Industrial and Societal Challenges