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Two-level graphs for muon-tomography inference

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Muon tomography is a useful imaging technique for studying volumes of interest by examining the scattering and absorption of cosmic muons which pass through them. Inferring properties of the volumes, however, is challenging since muons will scatter many times within the volume, the detectors involved have finite resolution, and each muon only ever traverses a sub-potion of the whole volume.

Traditional inference approaches either function by extrapolating incoming and outgoing muon trajectories inside the volume and assign the entire scattering to a single "point of closest approach", or use a maximum likelihood fit to infer material densities. The PoCA approach being inherently biassed, and the fit being challenging to implement. In both cases the volume can be discretised into voxels.

As part of ongoing work to develop a fully-differentiable pipeline for optimising muon tomography detectors (TomOpt - see Ref*), we have studied how graph neural networks are applicable to inferring properties of the volumes of interest by learning representations of the available data in two stages: a representation of the muons for each voxel, and a representation of the surrounding voxels for each voxel. Not only does such a setup allow the full population of muons to be adequately exploited in all parts of the volume, but the resulting per-voxel representations can be easily adapted for predictions at both the voxel and volume level.

In this presentation we present results on several benchmark examples, and discuss the pros and cons of such an approach.

*MODE et al. (2022) Toward the End-to-End Optimization of Particle Physics Instruments with Differentiable Programming: a White Paper, arXiv:2203.13818 \[physics.ins-det\]

Primary author: Dr STRONG, Giles Chatham (Universita e INFN, Padova (IT))

Presenter: Dr STRONG, Giles Chatham (Universita e INFN, Padova (IT))

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