

Enhanced GNN models for track reconstruction with ATLAS ITk

mardi 27 septembre 2022 14:40 (20 minutes)

Graph Neural Network (GNN)-based algorithms have been shown to produce competitive physics performance for the reconstruction of tracks from charged particles (« tracking ») during the future high-luminosity phase of the LHC (HL-LHC). Initial studies [1,2] of these algorithms were based on the dataset from the TrackML challenge [3], i.e. a simulated dataset created with a number of simplifying assumptions. The most recent studies are based on detailed simulations of the future ATLAS Inner Tracker (ITk) [4,5]. GNN-based algorithms now appear as competitive solutions for the future generation of charged particle track reconstruction algorithms which will have to be put into production for the HL-LHC.

We present in detail the architecture of the Message Passing Neural network (MPNN) model used to obtain these results. We focus on the limitations and on potential shortcomings of the present algorithms in specific regions of the detector. We present new approaches that are being explored to overcome these limitations, like heterogeneous versions of the MPNN model or the use of weights to obtain class ratio and/or graph topology region balance in the loss function. We discuss the interest of evolving the model towards a Graph Transformer-type architecture including attention mechanisms, and of adding topological or detector-geometry-oriented positional encodings to the current encodings of detector hits in euclidian space.

[1] Towards a realistic track reconstruction algorithm based on graph neural networks for the HL-LHC, C.Rougier et al., vCHEP 2021, https://www.epj-conferences.org/articles/epjconf/pdf/2021/05/epjconf_chep2021_03047.pdf

[2] Physics and Computing Performance of the Exa.TrkX TrackML Pipeline, D. Murnane et al., vCHEP 2021, <https://cds.cern.ch/record/2767568?ln=fr>

[3] TrackML challenge: <https://www.kaggle.com/c/trackml-particle-identification>

[4] Graph Neural Network track reconstruction for ATLAS ITk, D. Murnane et al., IML 2022, <https://cds.cern.ch/record/2809518/files/ATLAS-ITK-SLIDE-2022-119.pdf>

[5] ATLAS ITk Track Reconstruction with a GNN-based pipeline, C.Rougier et al., CTD 2022, <https://cds.cern.ch/record/2815578>

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Classification de Session: Tuesday afternoon

Classification de thématique: 1 ML for object identification and reconstruction