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Graph Neural Network Track Reconstruction for the ATLAS ITk Detector

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Graph Neural Networks (GNNs) have been shown to produce high accuracy performance on a variety of HEP tasks, including track reconstruction in the TrackML challenge, and tagging in jet physics. However, GNNs are less explored in applications with noisy, heterogeneous or ambiguous data. These elements are expected from ATLAS Inner Tracker (ITk) detector data, when it is reformulated as a graph. We present the first comprehensive studies of a GNN-based track reconstruction pipeline on ATLAS-generated ITk data.

Significant challenges exist in translating graph methods to this dataset. We analyze several approaches to low-latency and high-efficiency graph construction, including heuristics-based construction, discrete mappings of spacepoints to detector modules, and neural network learned mappings. We also extend these ideas to mappings of spacepoint doublets for more performant graph construction. Innovations in GNN training are required for ITk, and we discuss memory management for the very large ITk point clouds, and novel constructions of loss for noisy spacepoints and background tracks.

Track candidates constructed from GNN link prediction may always suffer some inefficiency, particularly on noisy point clouds. We present several methods for post-processing GNN output for either very fast triplet seeding on GPU, or for recovering efficiency with learned embeddings of tracklets and with Kalman Filters. Finally, the performance of several configurations of GNN architecture based on the Interaction Network are considered, for various hardware and latency constraints.

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