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Graph Neural Networks for charged-particle track reconstruction

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In particle collider experiments, such as the ATLAS and CMS experiments at CERN, high-energy particles collide and shatter into a plethora of charged particles traversing a silicon detector and leaving energy deposits, or hits, on the detector modules. The reconstruction of charged-particle trajectories (tracks) from these hits, an integral part in any physics program at the Large Hadron Collider (LHC), ranks among the most demanding tasks in offline computing, and, due to an increased level of pileup, faces steep challenges in computational resources and complexity in the upcoming High Luminosity phase (HL-LHC). Track pattern recognition algorithms based on Graph Neural Networks (GNNs) have been demonstrated as a promising approach to these problems [1,2,3,4]. In this contribution, we present the first machine learning pipeline developed for track reconstruction in silicon detectors. Motivated by the ATLAS ITk, we propose to apply this AI algorithm at an early stage in the processing chain, on every recorded event using raw data from the tracking detector. We discuss machine learning techniques employed in various stages of our pipeline, including building graphs from detector outputs, graph filtering, edge classification with GNNs, and graph segmentation to yield tracks. We address the unique memory and time constraints associated with running a deep-learning algorithm at a low-level data processing stage, and how we meet these requirements with our model design. The pipeline's physics and computational performance will be demonstrated, along with optimisations that reduce computational cost without affecting physics performance. We also describe the challenges to deployment in the HL-LHC and our steps toward a seamless integration into existing analysis software at CERN, highlighting our commitment to advancing AI-based track reconstruction for high-energy physics.

Reference:

[1] Biscarat, Catherine et al. "Towards a realistic track reconstruction algorithm based on graph neural networks for the HL-LHC". In: EPJ Web Conf. 251 (2021), p. 03047. doi: 10.1051/epjconf/202125103047. URL: https://doi.org/10.1051/epjconf/202125103047.

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