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Improving the line-segment tracking algorithm with machine learning for the High Luminosity LHC

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In this work, we present a study on how machine learning (ML) can be used to enhance charged particle tracking algorithms. In particular, we focus on the line-segment-based tracking (LST) algorithm that we have designed to be naturally parallelized and vectorized on modern processors. LST has been developed specifically for the Compact Muon Solenoid (CMS) Experiment at the LHC, towards the High Luminosity LHC (HL-LHC) upgrade, and we have shown excellent efficiency and performance results, leveraging a full simulation of the CMS detector. At the same time, promising ML solutions, mainly Graph Neural Networks (GNNs), for charged particle tracking have been emerging, based initially on the simplified TrackML dataset. Preliminary results from these studies suggest that parts of LST could be improved by ML. Thus, a thorough study of exactly how and where this might be done is described. First, a lightweight neural network is used in place of explicitly defined track-quality selections. This neural network recovers a significant amount of efficiency for displaced tracks, reduces false positives, and has little-to-no impact on the throughput. These results clearly establish that ML can be used to improve LST without penalty. Next, exploratory studies of GNN track-building algorithms are described, where LST is used to create the input graph. Then, an edge-classifier GNN is trained, and the efficiency of the resultant edge scores is compared with LST. These GNN studies provide insights into the practicality and performance of using more ambitious ML algorithms for HL-LHC tracking at the CMS Experiment.

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