T 97: Data, AI, Computing, Electronics IX (AI-based Object Reconstruction)

Time: Friday 9:00–10:30 Location: VG 2.102

T 97.1 Fri 9:00 VG 2.102

Hit-Filtering with Graph Neural Networks for Tracking at Belle II — •Greta Heine, Giacomo De Pietro, and Torben Ferber — Karlsruher Institut für Technologie (KIT), Karlsruhe, Deutschland

Over the next few years, the Belle II Experiment will increase its instantaneous luminosity, which will also lead to a significant increase in the beam background, affecting the efficiency of both online and offline tracking algorithms. To overcome this challenge and to facilitate the identification of displaced vertices for the discovery of new physics phenomena, Belle II needs more robust tracking algorithms.

Graph Neural Networks (GNNs) are a powerful class of machine learning models capable of adapting to irregular geometries and modeling complex relationships within detector hits. In this work, GNNs are used to filter background hits in the Belle II Central Drift Chamber based on edge classification using detector-level information. By filtering the background hits, both the track fitting performance as well as the computational efficiency can be improved at high background levels.

This talk will present the performance of this filtering approach for offline tracking algorithms on both simulated and real data, showing significant improvements in tracking efficiency and robustness under varying background conditions.

T 97.2 Fri 9:15 VG 2.102

End-to-End Multi-Track Reconstruction using Graph Neural Networks at Belle II — •Lea Reuter, Giacomo De Pietro, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Displaced vertices are an important signature in Standard Model analyses involving K_S and many searches for New Physics. However, the current Belle II tracking algorithm falls short when dealing with particles that decay after a large distance, resulting in a decrease in tracking efficiency with increasing displacement.

In this work, we show a novel track finding algorithm that combines the Object Condensation algorithm with Graph Neural Networks. This approach simultaneously identifies all tracks in an event and determines their respective parameters. Additionally, we integrated the new track finding algorithm into the Belle II analysis software framework.

Our results show significant reconstruction improvements of more than 50% for a long-lived particle within the GeV mass range and a lifetime of 10 cm in comparison to the existing Belle II track finding algorithm. This improvement is achieved while maintaining a similar efficiency and fake rate for prompt tracks originating from the interaction point.

T 97.3 Fri 9:30 VG 2.102

Graph Neural Networks for Track Reconstruction at the ATLAS Event Filter — •Giulia Fazzino, Sebastian Dittmeier, and André Schöning — Physikalisches Institut, Universität Heidelberg, Germany

In its High-Luminosity phase, the LHC will collide particles at unprecedented luminosity scales, drastically increasing the number of interactions per bunch crossing and thus introducing the need for upgrades in the ATLAS Trigger System. In parallel, a new tracking detector, the Inner Tracker (ITk), will be installed. Its data will be used by the Event Filter in the last step of the trigger chain, for track reconstruction and, finally, event selection.

To minimize the computing resources needed by the Event Filter, the usage of hardware accelerators such as GPUs or FPGAs is studied, and significant effort is put into the development of a tracking algorithm based on Graph Neural Networks (GNNs). Such a method would first build a graph by connecting the hits in the ITk, and subsequently generate track candidates from it thanks to a GNN and a segmentation algorithm. The construction of the graph can be conducted in several ways, one of which is to use Metric Learning, a machine learning procedure connecting hits depending on their distances in a feature space.

This talk will provide an outline of GNN-based tracking for the ATLAS Event Filter, with a focus on Metric Learning, and present results on the realization and optimization of such a graph construction method for FPGA deployment.

T 97.4 Fri 9:45 VG 2.102

GCNN-based Hybrid Reconstruction of Cosmic Rays with IceAct and IceCube — •Lars Marten, Philipp Behrens, Shuyang Deng, Lasse Düser, Jonas Häussler, Lars Heuermann, Sönke Schwirn, Philipp Soldin, Julian Vogt, and Christopher Wiebusch — RWTH Aachen - III. physikalisches Institut B, Aachen, Germany

IceAct is an array of Imaging Air Cherenkov Telescopes stationed at the South Pole as part of the IceCube Neutrino Observatory. Among its goals is the combined measurement of air showers together with the in-ice detector IceCube and the IceTop surface detector. Such hybrid measurements grant the advantage of complementary information improving reconstruction capabilities. Our graph convolutional neural network has been developed using a simulation of the IceAct array with the purpose of reconstructing the direction of the primary particle of an air shower. In this talk we will present an updated version of this neural network with additional reconstruction capabilities such as primary particle energy and relative shower core position. Also, we will present our advances in including hybrid data into our network prediction.

T 97.5 Fri 10:00 VG 2.102

Advanced Northern Tracks Selection using a Graph Convolutional Neural Network for the IceCube Neutrino Observatory: Network Architecture — •Philipp Soldin, Philipp Behrens, Jakob Böttcher, Shuyang Deng, Lasse Düser, Philipp Fürst, Leon Hamacher, Michael Handt, and Christopher Wiebusch for the IceCube-Collaboration — RWTH Aachen University

The IceCube Neutrino Observatory is a large neutrino detector located in the ice at the geographic South Pole. It detects atmospheric and astrophysical neutrinos through the Cherenkov radiation emitted by secondary particles using over 5,000 photomultipliers (PMTs). One of the primary challenges is effectively distinguishing between muons induced by either neutrinos or air-showers. To address this, the Advanced Northern Tracks Selection (ANTS) employs a deep graph convolutional neural network (GCNN). This neural network takes advantage of the node-like structure of the PMT array's geometric arrangement and processes raw sensor data. By leveraging both local and global event features, the ANTS GCNN enhances classification performance. This presentation focuses on the architecture of the ANTS GCNN and evaluates its performance in rejecting background interference from air-shower-induced muons. We assess the accuracy and resolution of the reconstruction, and computational efficiency, showing significant improvements over traditional methods across various muon track topologies.

T 97.6 Fri 10:15 VG 2.102

Exploring position reconstruction of HPGe detector events in LEGEND with a deep neural network — •Christoph Seibt[1] and Aobo Li[2] — [1]TU Dresden, Germany — [2]UCSD, USA

LEGEND is searching for neutrinoless double-beta ($0\nu\beta\beta$) decay, using High-Purity Germanium (HPGe) crystals enriched in ^{76}Ge as both source and detector. With its second phase, LEGEND-1000, the experiment uses 1 ton of germanium crystals to reach a discovery potential of half-lives greater than 10^{28} years. HPGe detectors measure pulse shapes of excellent quality, which are analyzed to reconstruct the events energy and reject background-induced events. These pulse shapes depend on the location of the events in the detector. This work leverages pulse shape topology to extract positional information, utilizing a recurrent-type neural network to overcome the limitations of classical methods. Simulated pulses from random event locations are used for training and testing. The current progress on a deep neural network for position reconstruction is displayed in this presentation. It shows the current reconstruction potential and first applications to specifying detector parameters.

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