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Semi-supervised Graph Neural Networks for Pileup Noise Removal

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The high instantaneous luminosity of the CERN Large Hadron Collider leads to multiple proton-proton interactions in the same or nearby bunch crossings (pileup). Advanced pileup mitigation algorithms are designed to remove this noise from pileup particles and improve the performance of crucial physics observables. This study implements a semi-supervised graph neural network for particle-level pileup noise removal, by identifying individual particles produced from pileup. The graph neural network is firstly trained on charged particles with known labels, which can be obtained from detector measurements on data or simulation, and then inferred on neutral particles for which such labels are missing. This semi-supervised approach does not depend on the neutral particle pileup label information from simulation, and thus allows us to perform training directly on experimental data. The performance of this approach is found to be consistently better than widely-used domain algorithms and comparable to the fully-supervised training using simulation truth information. The study serves as the first attempt at applying semi-supervised learning techniques to pileup mitigation, and opens up a new direction of fully data-driven machine learning pileup mitigation studies.
In the semi-supervised pileup mitigation study, model transferability from charged particles to neutral particles depends on the assumption that the features of training charged particles and testing neutral particles are from the same distribution. This motivates us to think of a broader problem that the simulation data and experimental data have different distributions and how the model may generalize. We would like to present some of our recent findings on how to make graph neural networks more generalizable when such distribution gap exists.

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