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Equivariant Graph Neural Networks for Charged Particle Tracking

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A broad range of particle physics data can be naturally represented as graphs. As a result, Graph Neural Networks (GNNs) have gained prominence in HEP and have increasingly been adopted for a wide array of particle physics tasks, including particle track reconstruction. Most problems in physics involve data that have some underlying compatibility with symmetries. These problems may either require, or at the very least, benefit from models that perform computations and construct representations that reflect these symmetries. In this work, we explore the application of symmetry group equivariance to GNNs within the context of charged particle tracking in pileup conditions similar to those expected at the high-luminosity Large Hadron Collider. In particular, we investigate whether rotationally-equivariant GNNs can perform competitively and yield models that either contain fewer, more expressive learned parameters or are more efficient vis-à-vis data and computational requirements. To our knowledge, this is the first study exploring equivariant GNNs for a track reconstruction use case. Additionally, we perform a side-by-side comparison of equivariant and non-equivariant architectures over evaluation metrics that capture both outright tracking performance as well as the track-building power-to-weight ratio of physics-constrained GNNs.

Significance

While there has been recent progress in developing symmetry equivariant GNNs for particle physics, they have mostly been limited to tasks like jet tagging. The presented work is perhaps the first study that discusses the application of equivariant graph neural network architectures to a particle track reconstruction task. It represents an essential contribution toward future architectures that are potentially more robust under newer computational paradigms.

References

Experiment context, if any

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