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Optimal Equivariance from the Matrix-Element Method

The Matrix-Element Method (MEM) has long been a cornerstone of data analysis in high-energy physics. It leverages theoretical knowledge of parton-level processes and symmetries to evaluate the likelihood of observed events. We combine MEM-inspired symmetry considerations with equivariant neural network design for particle physics analysis. Even though Lorentz invariance and permutation invariance over all reconstructed objects are the largest and most natural symmetry in the input domain, we find that they are suboptimal in most practical search scenarios. We propose a longitudinal boost-equivariant message-passing network. We present numerical studies demonstrating MEM-inspired architectures achieve new state-of-the-art performance in distinguishing di-Higgs decays to four bottom quarks from the QCD background, with enhanced sample and parameter efficiencies. This synergy between MEM and equivariant deep learning opens new directions for physics-informed architecture design, promising more powerful tools for probing physics beyond the Standard Model.

AI keywords

Group Equivariance, Message Passing Neural Networks, Point Clouds

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