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Quantum Graph Neural Networks for Track Reconstruction in Particle Physics and Beyond

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The Large Hadron Collider (LHC) at the European Organisation for Nuclear Research (CERN) will undergo an upgrade to further increase the instantaneous rate of particle collisions (luminosity) and become the High Luminosity LHC. This increase in luminosity, will yield many more detector hits (occupancy), and thus measurements will pose a challenge to track reconstruction algorithms being responsible to determine particle trajectories from those hits. Similar challenges exist in non-high energy physics (HEP) trajectory reconstruction use-cases. High occupancy, track density, complexity and fast growth exponentially increase the demand of algorithms in terms of time, memory and computing resources.
Graph Neural Networks are currently explored for HEP, but also non-HEP trajectory reconstruction applications. Use of Quantum Computers in HEP applications is also a new trend with their feature of evaluating a very large number of states simultaneously are therefore good candidates for such complex searches in large parameter and graph spaces.
In this work, we discuss the use of Parametrized Quantum Circuits (PQC) as an additional hidden layer to a previously suggested classical Graph Neural Network model (HEP.TrkX) for particle track reconstruction. The new model, which we call the Quantum Graph Neural Network (QGNN) model, is a hybrid model that can handle graph data and perform edge classification with the help of Quantum Circuits that are compatible with Noisy Intermediate Scale Quantum (NISQ) devices. We further discuss the track reconstruction as an analogous problem with flight trajectory reconstruction in aviation industry and provide a non-HEP application for the QGNN model. The initial model that can perform edge classification on HEP data was presented at the Connecting the Dots workshop.

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