Graph Methods for Particle Tracking

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The HL-LHC [1] era will bring unprecedented challenges in the area of tracking especially at the trigger level as each beam crossing will result in hundreds of interactions producing thousands of tracks, which must be analyzed leading to a trigger decision within 2.5 us. The particle tracking algorithms currently in use for track seeding and track reconstruction are algorithmically complex and have begun to reach their limit in the optimization that can be achieved; they can't scale effectively to meet HL-LHC needs. More innovative algorithms are necessary in order to achieve optimal processing capacity to match the higher event rate. Therefore, it is necessary to explore and develop new machine learning algorithms that can run deep learning techniques [2] in order to efficiently process the track reconstruction data at a fast enough rate.

Graph neural networks are a subset of machine learning methods that model data as a graph and have many potential applications in particle physics. In particular, using GNN methods to calculate particle tracking promises to improve performance by acceleration at the seed tracking level. Implementing GNN methods on the software side of the CMS pixel detectors and training the networks using deep learning techniques is of high value to the LHC, with the possibility to allow the experiments to meet the challenges of the HL-LHC era and maximize their physics potential.

These are possible tasks and time breakdown for what I would accomplish:

Project setup and survey of possible GNN architectures and construction methods to be evaluated (20 hours)

Define metrics for performance (20 hours)

Learn to use existing setup (20 hours)

For each candidate GNN architecture do the following: (100 hours per architecture)

-- Implement GNN

-- Train networks

-- Evaluate methods and iterate on algorithm implementation

-- report progress to mentor

Evaluate and compare performance metrics for candidate architectures (20 hours)

Prepare summary report (20 hours)

Weekly schedule: I propose to work 15 hours per week during the semester, as I am a full-time student.

Student background:

I am a computer science student interested in the application of computer science principles to scientific problems. I find machine learning very interesting and I aim to be able to make a contribution to the field of physics while learning more about the implementation of neural network algorithms. I see this project as an ideal way to do this, as it has the potential to enable further research within the HL-LHC, and I see the implementation of GNN's to be a very useful skill for me to learn and apply.

References

[1]G. Apollinari et al. “High Luminosity Large Hadron Collider HL-LHC”. In:CERN YellowReport5 (2015), pp. 1–19.DOI:10 . 5170 / CERN - 2015 - 005 . 1. arXiv:1705 . 08830[physics.acc-ph].
[2] D. Guest, K. Cranmer, D. Whiteson, “Deep Learning and Its Application to LHC Physics”, Annu. Rev. Nucl. Part. Sci. 2018. 68:1–22https://doi.org/10.1146/annurev-nucl-101917-021019