A3D3 HEP activities

Mia

Inputs to annual report: Part I accomplishments

- What are the major goals of the project? Major activities, Specific objectives, Significant results
- The overall status of the High Energy Physics(HEP) thrust is that the PIs are actively in applying Machine Learning (ML) methods for the Large Hadron Collider (LHC) Run-3 data-taking that is scheduled to start in Summer 2022, as well as the planned High-Luminosity LHC(HL-LHC) operation. The HEP PIs are leading numerous efforts in developing ML methods suitable for the sparse point-cloud type of data sets collected by the ATLAS and CMS experiments, as well as tackling the technical challenges in realizing such methods by enhancing the capabilities of the HLS4ML tool and co-processor as-a-service computing paradigm. A broad range of applications in reconstruction, fast detector simulation, unconventional searches with anomaly detection are being pursued by the HEP PIs.
- List of project descriptions in quarterly report overleaf document. (11 projects in total, not sure how to share the link, Phil is the owner of the document)

Inputs to annual report: Part II Key outcomes

- **ADD: Projects, postdocs and students mentored in each project (PLEASE PROVIDE inputs)**
  - Particle flow (PF) reconstruction with explainable Graph Neural Network (GNN)
  - Semi-supervised Graph Neural Network Puppi: Tianchun Liu, Shikun Li (Purdue undergrads), Lisa Paspalaki (Purdue postdoc)
  - Machine learning for HEP simulations
  - Energy corrections with GNNs
  - Calorimetry Clustering with SPVCNN
  - Using Autoencoder Latent Spaces to Derive Level-1 Hardware Trigger
  - GNN-based anomaly detection in CMS Level-1 (L1) Trigger
  - B Jet tagging in CMS Level-1 (L1) Trigger based on hardware
  - tau3mu reconstruction using GNN : Siqi Miao (Purdue Ph.D), Ben Simon (Purdue undergrad)
  - ML-based missing transverse momentum estimation in the CMS Level-1 (L1) Trigger
  - LLP jet tagging in the CMS Level-1 trigger
- Disseminate the results: conferences and seminars
  - APS April meeting: “Calibration of electrons and photons in the CMS ECAL with graph neural networks”.
  - Seminar at Boston University. April 1st. (Mia Liu)
  - Graph Puppi:
    - CERN IML meeting: Inter-experiment Machine Learning workshop (CERN) May 9 -12
    - NeurIPS AI4Science Workshop

Part III products

“Semi-supervised Graph Neural Networks for Pileup Noise Removal”, paper submitted to EPJC. https://arxiv.org/abs/2203.15823
“ MLPF with CMS data”, ACAT 2021, https://arxiv.org/abs/2203.00330
“Information bottleneck-Guided Stochastic Attention Mechanism for Interpretable Graph Learning”: accepted to ICML 2022. https://arxiv.org/abs/2201.12987

“Physics Community Needs, Tools, and Resources for Machine Learning." Contribution to Snowmass Summer Study 2022.

Applications and Techniques for Fast Machine Learning in Science. (Accepted by Frontiers Research Topic - Efficient AI in Particle Physics and Astrophysics in Frontiers Big Data and AI in High Energy Physics (2021)

Part IV Participants & Other Collaborating Organizations

1. Complete the form

https://docs.google.com/spreadsheets/d/1RBcg-PKcPvmC1Xv_8KC8R7BjJev1M_tbayAxFA0rLh0/edit?usp=sharing

2 .What other organizations have been involved as partners?

3. Were other collaborators or contacts involved? If so, please provide details.

Part V Impacts

1. What is the impact on the development of the principal discipline(s) of the project?

2. What is the impact on other disciplines?

Scientific challenges in HEP domain inspired new machine learning formalism studies in interpretable graph neural networks. These interpretable GNN studies are inspired by and can be applied to the tau3mu problem, it is also potentially applicable to other point cloud data such as neuroscience imaging datasets/ protein folding datasets.

The hls4ml project and as-a-service approach in integrating heterogeneous computing platforms in real-time challenges of HEP apply to other science domains such as edge devices for neuroscience data collection/real-time alert in MMA.

3. What is the impact on the development of human resources?

4. What was the impact on teaching and educational experiences?

5. What is the impact on institutional resources that form infrastructure?