***Snowmass Letter of Interest*, Topic Areas: CompF03, CompF07**

Expansion of HEP-ML Education

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ABSTRACT

While machine learning (ML) is becoming a commonly used tool within the high energy physics (HEP community), many of our students and postdoctoral researchers come into this field with little to no background in ML. This can lead to long startup times for analyses and a lack of innovation towards using new ML techniques. While the community has put some effort into educating itself in the uses of ML, we think there is still work to be done to make these techniques a standard tool, rather than a novel approach. This LoI is written in support of efforts to bring about new community wide ML education opportunities as well as structural changes which will further students' early education in the mastery of ML-based methods.

1 Introduction and Existing Resources

The high energy physics (HEP) research community has a strong background in education. Not only do many of its members come from universities and centers for education, but the community also seeks to provide additional education resources when necessary. In recent years machine learning (ML) techniques for detector and accelerator control, data simulation, reconstruction, and physics analysis have become commonplace [1–5]. However, the particle physics community in the United States has been slow to add ML as a component in its educational curriculum. Even more concerning is that the community needs to be able to educate its members who did not have formal training in ML when they went through an undergraduate or graduate institution. This may be an over generalization, but it is nevertheless true in some cases.

In the last decade the community has made an effort to remedy this situation, with mixed results. We can see numerous examples of tutorials, workshops, and schools both within the HEP community and in the broader data science (DS) community. The CERN Inter-Experimental LHC Machine Learning Working Group [6] has put together an extensive list of these resources [7], though there are notable examples which are missing from this document [8–10]. This has, without a doubt, helped to increase the number of people who are able to take apply ML to their HEP related activities. Furthermore, there certainly are researchers who, despite their background in physics, have become experts in the adaptation of ML methods for use in HEP and are performing novel ML research. Certainly the DOE and NSF have already signaled their belief that HEP researchers have a role to play in applying AI tool and furthering that field of research [11–14].

We believe it will become ever more crucial that both our young and experienced researchers have a working understanding of ML tools. We would like to see a continuation of community efforts towards raising he level of ML proficiency among current researchers by providing in-depth and innovative schools. It would also be nice to see movement towards the addition of DS and ML studies within the physics curriculum at our educational institutions. All of this will take cooperation from the entire HEP community and not just the efforts of individual experimental collaborations.

References

[1] Kim Albertsson et al. "Machine Learning in High Energy Physics Community White Paper". In: *Proceedings, 18th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 2017)*. Vol. 1085. 2018, p. 022008. DOI: 10.1088/1742-6596/1085/2/022008. arXiv: 1807.02876 [physics.comp-ph].

[2] Alexander Radovic et al. "Machine learning at the energy and intensity frontiers of particle physics". In: *Nature* 560 (2018), p. 41. DOI: 10.1038/s41586-018-0361-2.

[3] Dan Guest, Kyle Cranmer, and Daniel Whiteson. "Deep Learning and its Application to LHC Physics". In: *Ann. Rev. Nucl. Part. Sci.* 68 (2018), p. 161. DOI: 10.1146/annurev-nucl-101917-021019. arXiv: 1806.11484 [hep-ex].

[4] Dimitri Bourilkov. "Machine and Deep Learning Applications in Particle Physics". In: *Int. J. Mod. Phys. A* 34 (2020), p. 1930019. DOI: 10.1142/S0217751X19300199. arXiv: 1912.08245 [physics.data-an].

[5] Fernanda Psihas et al. "A Review on Machine Learning for Neutrino Experiments". In: (Aug. 2020). arXiv: 2008.01242 [physics.comp-ph].

[6] Inter-Experimental LHC Machine Learning Working Group. *IML*. (accessed August 28, 2020). URL: https://iml.web.cern.ch/.

[7] Matthew Feickert et al. *iml-wg/HEP-ML-Resources: 2019*. Version 2019. Jan. 2020. DOI: 10.5281/zenodo.3626294. URL: https://doi.org/10.5281/zenodo.3626294.

[8] The CMS Collaboration. *CMS Data Analysis School*. 2020 (accessed on August 28, 2020). URL: https://lpc.fnal.gov/programs/schools-workshops/cmsdas.shtml.

[9] *Hands-on Advanced Tutorial Sessions at the LPC*. 2020 (accessed on August 28, 2020). URL: https://lpc.fnal.gov/programs/schools-workshops/hats.shtml.

[10] IRIS-HEP. *ML4Jets Workshop*. 2020 (accessed on August 28, 2020). URL: https://iris-hep.org/projects/ml4jets.html.

[11] Lauren Biron. *White House Office of Technology Policy, National Science Foundation and Department of Energy announce over $1 billion in awards for artificial intelligence and quantum information science research institutes*. Fermi National Accelerator Laboratory, 2020 (accessed on August 28, 2020). URL: https://news.fnal.gov/2020/08/white-house-office-of-technology-policy-national-science-foundation-and-department-of-energy-announce-over-1-billion-in-awards-for-artificial-intelligence-and-quantum-information-science-research-in/.

[12] National Science Foundation. *NSF advances artificial intelligence research with new nationwide institutes*. 2020 (accessed on August 28, 2020). URL: https://www.nsf.gov/news/special_reports/announcements/082620.jsp.

[13] U.S. Department of Energy. *Department of Energy to Provide $40 Million for Artificial Intelligence Research at DOE Scientific User Facilities*. Mar. 2020 (accessed on August 28, 2020). URL: https://www.energy.gov/articles/department-energy-provide-40-million-artificial-intelligence-research-doe-scientific-user.

[14] U.S. Department of Energy. *Department of Energy Announces $30 Million for Machine Learning and Artificial Intelligence Research*. Apr. 2020 (accessed on August 28, 2020). URL: https://www.energy.gov/articles/department-energy-announces-30-million-machine-learning-and-artificial-intelligence.