Analyzing Neutrino Interactions

Project:

I plan on using a modeling framework such as FINN to test improvements in analyzing the neutrino interactions recorded by the DUNE experiment. The DUNE experiment is based at Fermilab, and this experiment will be used to study neutrino physics by creating an intense beam of neutrinos and sending them through the Earth between two neutrino detectors so that physicists can study their interactions. One of the detectors will be underground at the Fermi National Accelerator Laboratory in Illinois, while the other will be set underground at the Sanford Underground Research Laboratory in South Dakota.

When these neutrinos interact with ematter, the result is similar to a pixelated image, and once that image comes through it can be broken up into pieces to be analyzed, and then the pieces can be put back together for a better image. This is why GPU algorithms and machine learning can work well for neutrino interactions. I plan on developing and optimizing an algorithm that would take in the image from the interaction, break down the image to analyze, and then put it back together so the physicists on the experiment can have a better idea of what is happening during the interactions. I will test this using simulated events prepared by the DUNE collaboration.

As there has been work done on various modelling methods for neutrino reconstruction, I'd like to start with an FPGA platform such as FINN, but may need to evaluate further to understand if there are options better suited to this problem. Specific concerns may be availability of resources for testing this platform. With my mentors I will take an initial period of time to survey existing work on this area. If FINN is a viable option, I will take some time to understand how to use it and apply it to the problem of reconstruction of neutrino interactions. I will then develop and optimize a model, and evaluate the performance.

Background:

Currently I am an undergrad student majoring in Computer Science with an emphasis in computer technology at the University of Wisconsin – Platteville. I would get help and simulation data from physicists at the University of Iowa (Professor Jane Nachtman, currently a mentor to IRIS-HEP fellow Orgho Neogi) and at Fermilab from members of the DUNE collaboration, and I would work with a Computer Science professor from the University of Wisconsin – Platteville (Professor Arghya Das).

I plan to work full-time(40 hours/week) on this project over the summer when I am not taking classes. The project timeline will be three months. I will meet regularly by zoom with the Iowa group for technical assistance and report to Professor Das on my progress. I will be starting this project on Monday, May 24, 2021, and ending on Friday, August 13, 2021.

Timeline (40 hours/week for 12 weeks):

- Weeks 1-2: Literature survey and evaluation of feasibility of FINN platform, or choice of other optimization platform
- Weeks 3-4: learn to use FINN, using tutorials and a test setup
- Weeks 5-8: access neutrino simulation data and develop model
- Weeks 9-11: optimization and testing of model
- Week 12: evaluation of model and preparation of report

Deliverables:

- A basic algorithm to break down and analyze the images from the neutrino interactions.
- Documentation on how the algorithm functions.
- Performance optimization and evaluation using FINN platform.
- A final report and presentation at the end of the project.

References:

Fermilab. (n.d.). *DUNE*. Deep Underground Neutrino Experiment. https://www.dunescience.org/.

Y. Umuroglu, et al.,FINN: A Framework for Fast, Scalable Binarized Neural Network Inference, FPGA'17: Proceeding of the 2017 ACM/SIGDA International Symposium on Field-Programmable Gate Arrays, Feb 2017,https://doi.org/10.1145/3020078.3021744