2023 Data Science Clinic Final Report

Detecting Neutrinos: Real-time Tagging and Triggering with Deep Learning AI for next generation particle imaging detectors.

Neutrinos are subatomic particles that are cousins of other subatomic particles like the electron, the muon, and the tau. Unlike their cousins they interact very weakly with matter, which makes them very hard to detect. The low detectability poses challenges to experimental studies, so many of the properties of neutrinos remain unknown. Studying neutrinos provide scientists with the opportunity to improve the standard model of physics and develop new areas for research

Fermilab studies neutrinos using a highly sensitive neutrino detector. Figure 1 below displays an example of a neutrino event image. While sensitive enough to measure events that contain neutrino events, the detector also records non-neutrino events such as cosmic rays and other particles. Currently, Fermilab stores all event data. Ideally, scientists would be able to filter event data in real time to save data for neutrino interactions and ignore all event data for cosmic rays.

The Fermi-Tag project developed two CNN-based models: a CNN model that makes prediction at the image level (Figure 2 below displays the confusion matrix output for the CNN model on training data) and a U-Net model that performs pixel-level prediction, which allows us to use more detailed information. Additionally, the team developed a framework to process and filter the incoming data from real-time running experiments in a way that allows future students that are part of the team to build on top of previous work.

For the next step, the team's potential paths for improvement include increasing the depth of the models to aim for better accuracy and exploiting the sparsity of the data to speed up training and prediction with submanifold sparse convolutional neural networks or graph neural networks.

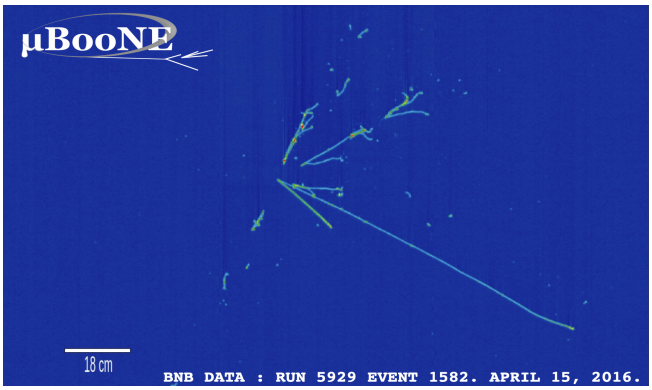

Figure 1: An Event with Neutrino Interactions from Fermilab Detectors

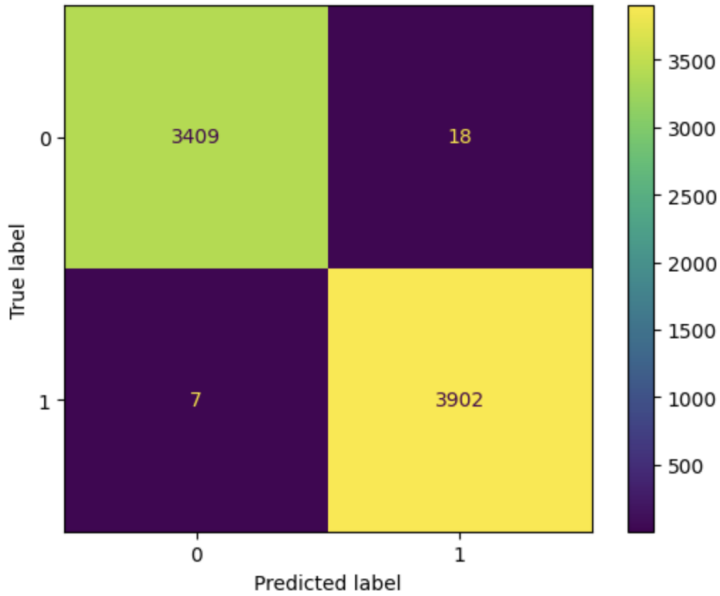

Figure 2: A Confusion matrix with Binary CNN Results