Neural Network Analysis on the NOvA Experiment

Twymun K. Safford, University of West Florida – SIST Program
Alex Himmel – Fermilab

Abstract

NOvA is collaboration of 180 scientists and engineers from 28 institutions which plans to study neutrino oscillations using the existing NuMI neutrino beam at Fermilab. The NOvA experiment is designed to search for oscillations of muon neutrinos to electron neutrinos by comparing the electron neutrino event rate measured at the Fermilab site with the electron neutrino event rate measured at a location just south of International Falls, Minnesota, 810 kilometers distant from Fermilab. If oscillations occur, the far site will see the appearance of electrons in the muon neutrino beam produced at Fermilab. The presence of background radiation obscures the desired particles and trails to be observed. Using neural network analysis, the goal of the project was to implement machine learning to automate the removal of background radiation to render pixel maps of the particle trajectories.

Background

Neutrinos are produced and detected via the weak interaction. Neutrinos have a charge with respect to the weak force, also known as a "flavor," which is labeled e, μ, and τ. Based upon superposition of states, the neutrino states of defined flavor are made by combining the neutrinos states that have definite mass. This is displayed in Figure 1.

The Problem

• The far detector is located at the Ash River, Minnesota. However, the far detector is subject to bombardment from billions of cosmic rays in any given second which obscures the visibility of neutrino particle trails of interest. To overcome this obstacle, images must be reconstructed with the absence of cosmic radiation which is time-consum ing and distracting from the tasks at hands.
• Examples of cosmic ray distribution and reconstruction slices used to isolate the neutrino trails are included below.

The Solution

• The NOvA project consists of three main elements:
  • An upgrade of the Fermilab accelerator complex
  • A 222 metric-ton near detector will be placed in a new, small, underground cavern adjacent to the existing underground cavern that houses the MINOS experiment.
  • A 15 metric-kiloton far detector will be located in a new facility located in Ash River, Minnesota, just south of International Falls, Minnesota and the U.S.-Canada border.

Results

The NOvA detector system includes a near detector and far detector. The far detector:
• 14 kTon at the Far Detector
• Consist of plastic cells filled with liquid scintillator
• Arranged in alternating directions for 3D reconstruction (cells are 3.8 cm X 5.9 cm)

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References