Applying convolutional neural networks to analyzing 4D data in the IceCube neutrino experiment

Project Overview

IceCube is a particle detector used in observing neutrinos, located at the South Pole. Strings of photo-detectors exist in a hexagonal lattice throughout the volume of the detector, and record light measurements over time. In theory, many of the neutrinos passing through IceCube are tau neutrinos, one of 3 types of this fundamental particle associated with the tau particle, however, it is very difficult to differentiate between the types, and thus tau neutrinos are very rarely provably observed. We believe that by searching for a double pulse light pattern, one that would be created by high energy tau neutrinos, we can detect such particles. Current methods attempt to search for these patterns using derivative based methods. However, convolutional neural networks have the unique property of giving significance to location of data, namely the correlation between data points that are close to each other. This is often applied to image-like data sets, but this project attempts to package 4 dimensional data into a form that is useful in interpretation by a CNN. Existing deep learning libraries do not apply naturally to IceCube, and this project will attempt to develop ways to apply the hexagonal, 4D geometry of IceCube to CNNs in such a way that we can find tau neutrinos.

Personal Role & Responsibilities

My role in the project is to be a research scientist. The general timeline of the project can be broken down into three phases: the research and learning phase, the development phase, and the testing phase. Of course these phases have some overlap, but they are concentrated chronologically. In learning and research, I will study the theory of convolutional neural networks, including recent developments. In development, I will apply the hexagonal, 4D geometry of IceCube to a form that we are able to perform convolutions on. We will test the performance of every adjustment on machines available in the lab.

Goals

The overall aim of the project is to create a method for searching for tau neutrinos in such a way that it overcomes the distinct properties of IceCube that make this task unique. Personally, I hope to learn as much as I can about deep learning, and to have an impact in my research. Concretely, I hope to develop skills such as TensorFlow knowledge and understanding of convolutional neural networks. I hope to see results that either greatly increase the accuracy of the network, or provide insights that I can understand and learn from.

Personal Statement

I am interested in this UROP because it will give me an opportunity to extend my machine learning knowledge in a hands on, cutting edge way. This is very important, as I plan to complete a masters degree in engineering with a concentration in machine learning. I am still very early in my machine learning career, as I have just began my first introductory class in machine learning this semester, and these experiences will surely take my education to the next level.