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Project Proposal

Topic: Convolutional neural network in High energy Physics

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I. Introduction

Over the last several decades, particle detection has seen a major boost in the field of High Energy Physics, These detectors are capable of processing data the data at high rate with every upgrade and run. This has led to a dramatic increase in data volumes that need to be efficiently analyzed in real time to reconstruct and filter events of interest.

Machine learning (ML) methods have been observed to have had a great impact in data processing and extremely effective in many different tasks across particle physics.

The Large Hadron Collider (LHC) at CERN serves as a perfect example. The LHC is the world's highest energy particle accelerator, operating at the highest data rates ever achieved. Its goal is to understand the very basic laws of nature and the building blocks of the universe.

In the first run of collecting data that concluded in 2012, the ground-breaking highlight was the discovery of the Higgs boson (popularized as God's particle) [1], [2]. The current data-taking campaigns are devoted to a full characterization of the Higgs boson properties and to the search for physics phenomena beyond the standard model of particle physics, this is necessary given the fact that the standard theoretical procedure predictions doesn't fit with what we observe, for example the existence of dark matter which is evident to us is an integral part in evolution of universe and existence of the reality as we know it today.

Jet: A jet is a narrow cone of hadrons and other particles produced by the hadronization of a quark or gluon in a particle physics or heavy ion experiment. When an object containing color charge fragments, each fragment carries away some of the color charge. In order to obey confinement, these fragments create other colored objects around them to form colorless objects. The ensemble of these objects is called a jet, since the fragments all tend to travel in the same direction, forming a narrow "jet" of particles. Jets are measured in particle detectors and studied in order to determine the properties of the original quarks.

II. Dataset Description

The dataset consists of 50000 jets samples with up to 100 particles in each jet. These 100 particles have been used to fill the 100x100 jet images. There are 53 features. [3]

III. Motivation

Machine learning is an important applied research area in particle physics, beginning with applications to high-level physics analysis in the 1990s and 2000s, followed by an explosion of applications in particle and event identification and reconstruction in the 2010s. [4]

Einstein famously related mass (m) to energy (E) via $E = mc^2$, where c is the speed of light in a vacuum. A powerful particle accelerator such as the LHC, which is 27 km in circumference, is therefore required to create particles orders of magnitude more massive than the proton, such as the Higgs boson. A Higgs boson is produced only once every few billion proton–proton collisions at the LHC. Many other interesting reactions occur orders of magnitude less often. To enable such data samples to be recorded in a reasonable time frame, the LHC collides nearly one billion protons persecond.

Machine learning methods are designed to exploit large datasets in order to reduce complexity and find new features in data. Typically, variables relevant to the physics problem are selected and a machine learning model is trained for classification or regression using signal and background events (or instances). Training the model is the most human- and CPU-time consuming step, while the application, the so called inference stage, is relatively inexpensive. BDTs and NNs are typically used to classify particles and events. They are also used for regression, where a continuous function is learned, for example to obtain the best estimate of a particle's energy based on the measurements from multiple detectors.

Neural Networks have been used in HEP for some time; however, improvements in training algorithms and computing power have in the last decade led to the so-called Deep Learning revolution, which has had a significant impact on HEP. Deep Learning is particularly promising when there is a large amount of data and features, as well as symmetries and complex non-linear dependencies between inputs and outputs, which is the case for the data obtained during each run of large hadron collider.

IV. Methodology for analysis.

Data set will be divided into train-test, 75:25. In terms of ML the problem considered is a classification problem and there are several methods for addressing it. To do a Jet identification task I will be using a Conv2D multiclass classifier. The problem consists in identifying a given jet as a quark, a gluon, a W, a Z, or a top, based on a jet image, i.e., a 2D histogram of the transverse momentum (p_T) deposited in each of $100x100$ bins of a square window of the (η, ϕ) plane, centered along the jet axis.

References

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