IRIS-HEP Fellows Program Project Proposal

Improving CICADA trigger algorithm

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Project Duration: 3 weeks

Proposed start date: 07 August 2024

Project Context and Description

In high-energy physics experiments, such as those conducted at the Large Hadron Collider (LHC), it is often impossible to record every particle collision due to the high rate of data. For this reason, dedicated low-latency algorithms (*triggers*) are deployed that decide in real-time if an event should be stored for further processing, reducing the initial event rate of 40 MHz down to roughly 1 kHz.

These triggers typically look for signatures in the detector that physicists deem interesting, such as highly energetic particles, or specific decay topologies. However, hand-crafted algorithms like these bear the risk of overlooking unknown types of signatures like they might occur in Beyond the Standard Model (BSM) scenarios.

The Calorimeter Image Convolutional Anomaly Detection Algorithm (CICADA) project [4] aims to provide a model-independent trigger based on anomaly detection. It uses low level CMS experiment's trigger calorimeter information as the input to convolutional auto-encoder to find anomalies produced during LHC proton-proton collisions. Quantization Aware Training and Knowledge Distillation are used to compress the model for sub-500 ns inference on Field-Programmable Gate Arrays.

Within the cylindrical calorimeters [1], trigger towers are specific regions where the energy deposits are summed and monitored. Each tower corresponds to a small section of the calorimeter, typically covering a range in pseudorapidit (η) and azimuthal angle (ϕ) [2]. With its initial convolutional layer, CICADA treats the (η, ϕ)-indexed energy deposits as ordered data, exploiting the proximity of neighboring pixels like in images from a digital camera. However, as the data actually stems from a cylindrical detector, there are relations between neighboring pixels that CICADA does not yet exploit.

Solution

In this project I will be implementing circular padding on convolutional neural networks and investigating its potential effects on the performance of CICADA. The models will be trained on simplified simulated dataset to gauge the potential impact of such padding techniques for the CICADA use case.

Project Timeline

Time frame Objectives

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Week 1	• Study auto-encoders and knowledge distillation, the basic principles of the Calorimeter Image Convolutional Anomaly Detection Algorithm (CICADA) • Select or generate a simplified dataset with the same cyclic nature as the calorimetric inputs for CICADA
Week 2	• Train a simple auto-encoder to replicate the input data and / or train a supervised student model on soft targets [3]. • Find the minimal model size that performs well • Implement circular padding for the model(s) above
Week 3	• Compare the models' performance with and without circular padding • Analyse and present the findings

References

1. Energy of Electrons and Photons (ECAL) | CMS Experiment, [https://cms.cern/detector/measuring-energy/energy-electrons-and-photons-ecal].

2. The CMS electromagnetic calorimeter project - CERN Document Server, [https://cds.cern.ch/record/349375].

3. Knowledge Distillation for Anomaly Detection, Adrian Pol et. Al, [https://arxiv.org/pdf/2310.06047].

4. The CICADA project (web), https://cicada.web.cern.ch/