CSE 524: Particle Track Reconstruction

Sriram

March 2019

1 Introduction

Scientists at Brookhaven National Laboratory (BNL) have conducted several particle accelerator experiments and collected the sensor's data. They have manually removed the noise in sensor's data and come up with the data set for the original sensor's data and noise removed data. They have recorded the readings of the outcome of the experiment, i.e identification of the particle generated from the particle accelerated experiment. They have manually performed the identification of the particle as well as removed the noise from the original image. I have worked on a specific experiment in which classification of the particle as well as the removal of noise are automated by the state of art Machine Learning techniques.

2 Background:

sPHENIX is a new detector planned for the RHIC facility at Brookhaven National Laboratory. The goal of sPHENIX is to understand the microscopic structure of the plasma and reveal how its strongly interacting nature arises from the underlying interactions of quarks and gluons described by quantum chromodynamics. sPHENIX will provide state-of-art capabilities for studies of the strongly interacting quark-gluon plasma using jet and heavy-flavor observables.

Scientists at BNL have conducted several particle collision experiments and collected the data of the particles which got exploded after the generation from the sensors. They have labelled the outcome i.e identifying the particle manually. Based on the final outcome, they have created a dataset in which they have removed the noise from the captured sensors data. More information regarding the experiment is presented in [2].

3 Dataset and processing of the data:

The dataset which they have made is not in structed form to be fed into machine learning model and they have presented the data in json file with the readings

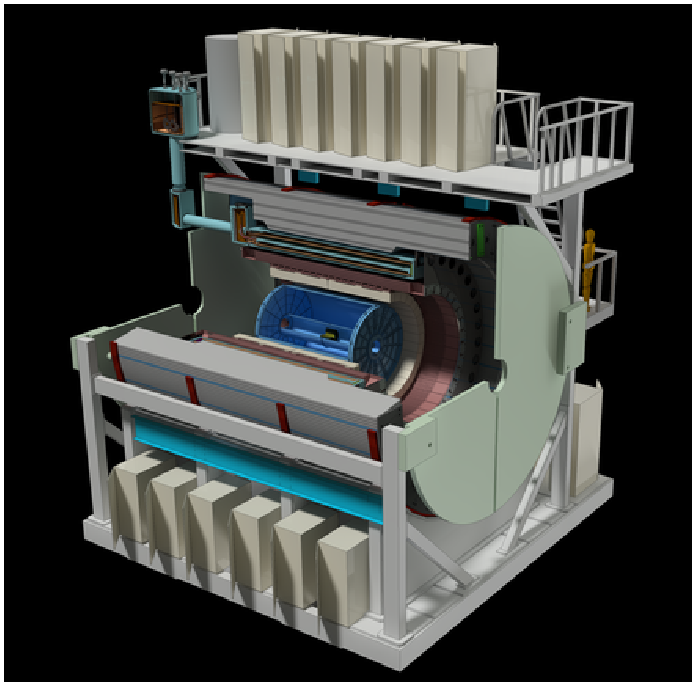

Figure 1: sPHENIX

(hits) and their particle outcomes. Based on the discussion with them, I have generated a script ”parsehit.py” to process the json file and collected the data in an image representation. The input representation is of size 1024*1024. But the training of the data using a neural network is time consuming. After having the discussion with the scientists, they were not looking for too much accuracy and they have suggested to go ahead with the max pooling of the image and I have generated both the input representation as the noise removed representation with the size 256*256. I will be referring input/output representation as image.

4 Optimization and Neural network

Initially, I have tried the classical data science techniques to generate the noise removal of the image and tried binary classification techniques for the particle identification. Since the results were not great with the classical approaches, I have explored state of the art deep learning neural networks for image reconstruction and finally went ahead with U-net[3]. I have tweaked the original U-net model by adding some extra layers. Please find the architecture in Figure 2 which I have used in my neural network. CONV2D is a convolution layer with non linear relu acitvation function and batch normalization. Similarly, DECONV2D is a deconvolution layer/transpose layer with relu activation and

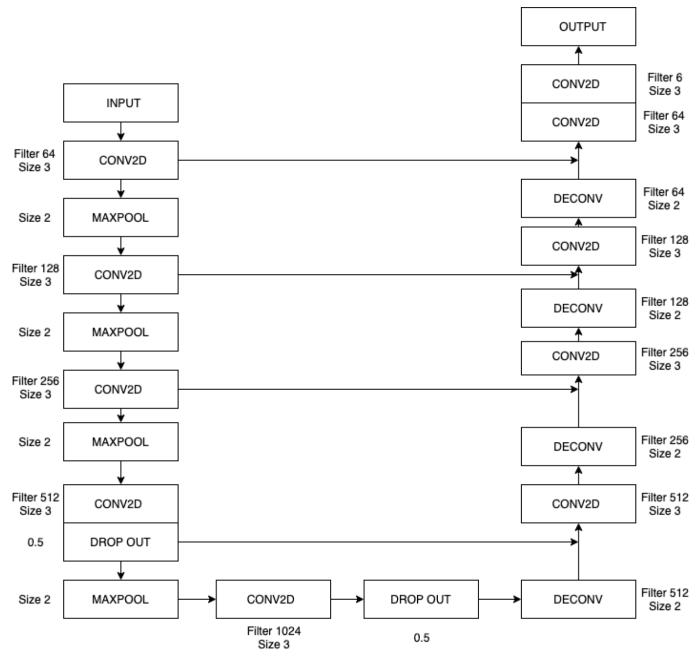

Figure 2: Reconstruction of the image

batch normalization. Other layers are standard with respect to the U-net. The loss function for this neural network is binary cross entrophy loss and Adam optimizer with learning rate of $1e-4$ is used for training. The Training for the network took 48 hours for 30 epochs on a GPU. Please find the images for the original image and the noise removed image, original noise removed image in Figure 3.

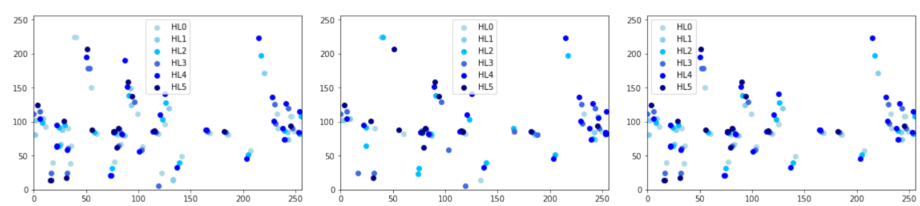

Figure 3: Input, Output, Groundtruth of ouput respectively

Since the features are being extracted from the U-net, I have used those features to classify the particle as we have the ground truth of the particle which was processed from json file. Please find the architecture in Figure 4 which I have used in my neural network.

I have freezed the parameters of the network which is same in U-net and trained the last layers of the network to classify the particle. Initially, I have

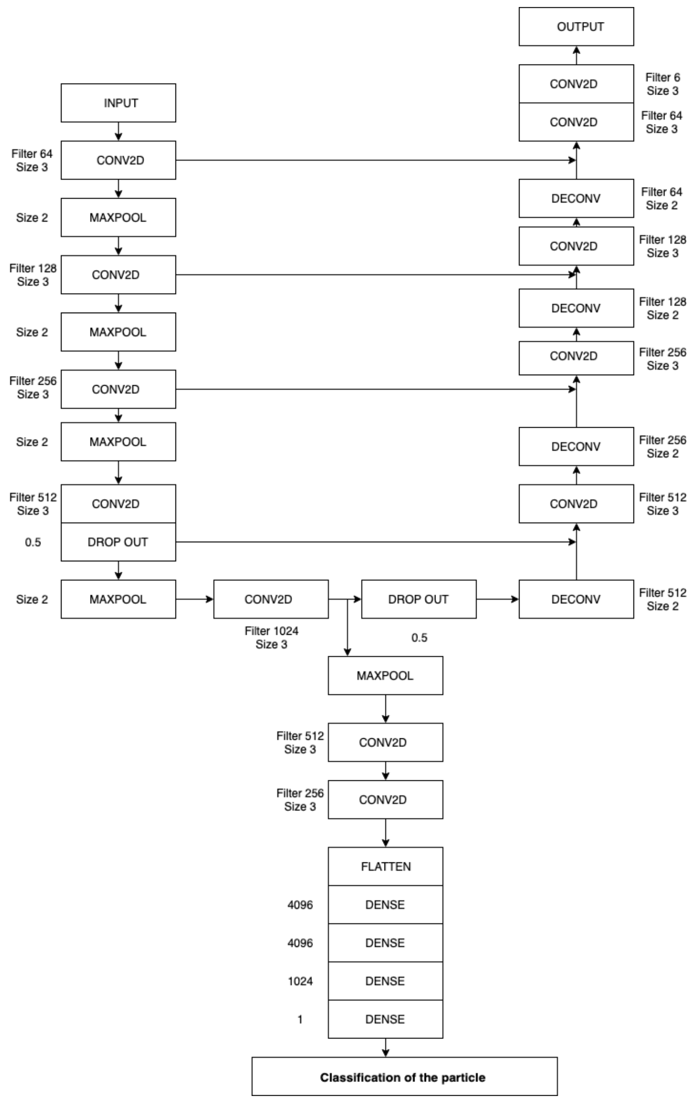

Figure 4: Classification of the particle

trained the network by taking 200 samples. Later, I have increased the training samples to 800 samples and then 1000 samples. The accuracy and the ROC curve on the test data is saturated after 800 samples. Please find the performance for 200 samples and 800 samples and it is better than the classical model. Please find the model and all the necessary files in [5]. This project has been finalized and they were satisfied with the results.

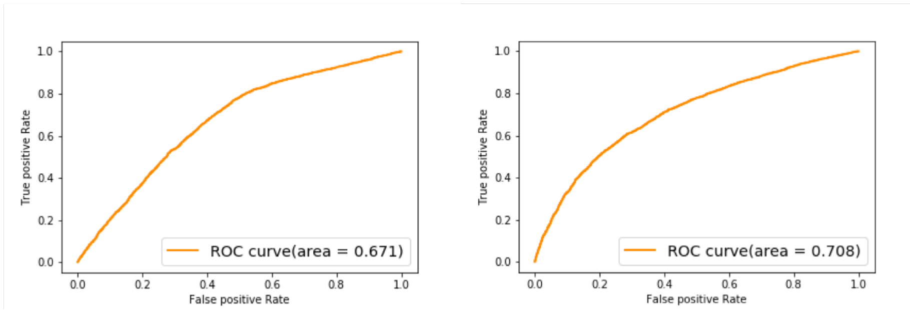

Figure 5: ROC curve for identification of the particle with input data of 200 samples and 800 samples respectively

5 References

1. https://www.sphenix.bnl.gov
2. https://www.phenix.bnl.gov/WWW/publish/mxliu/sPHENIX/MVTX/MVTX-Preproposal-v1.5-02012017.pdf
3. https://arxiv.org/abs/1505.04597
4. https://home.cern/science/accelerators/large-hadron-collider
5. https://github.com/sri123098/Particle_track_reconstruction