Deep Graph Neural Networks for Fast HGCAL Simulation

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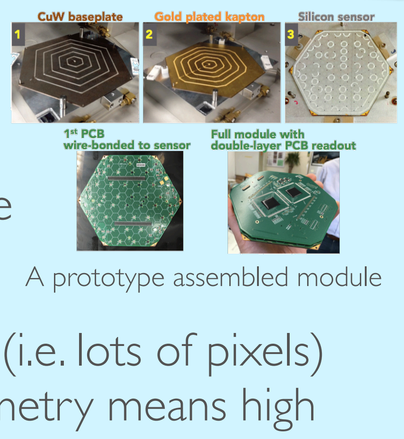
Institute for Research & Innovation in Software for High Energy Physics

Particle Simulations

- Simulations of events are very important in high energy physics
- Classical physics simulation programs such as GEANT4 are accurate but can be slow and inefficient
- Machine Learning is a potential alternative where we approximate the simulations at much higher speeds

HGCAL

- The High Granularity Calorimeter will be a major new addition to CMS as part of the HL-LHC upgrade.



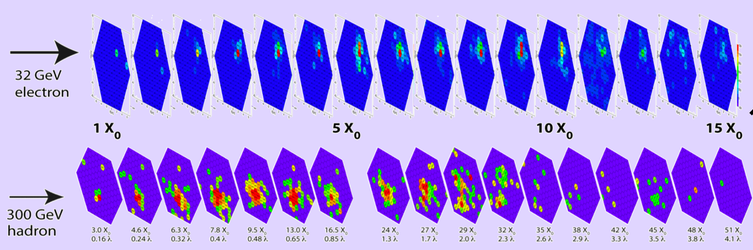
A prototype assembled module

- Very high granularity (i.e. lots of pixels) plus its irregular geometry means high computational effort

Machine Learning at CERN

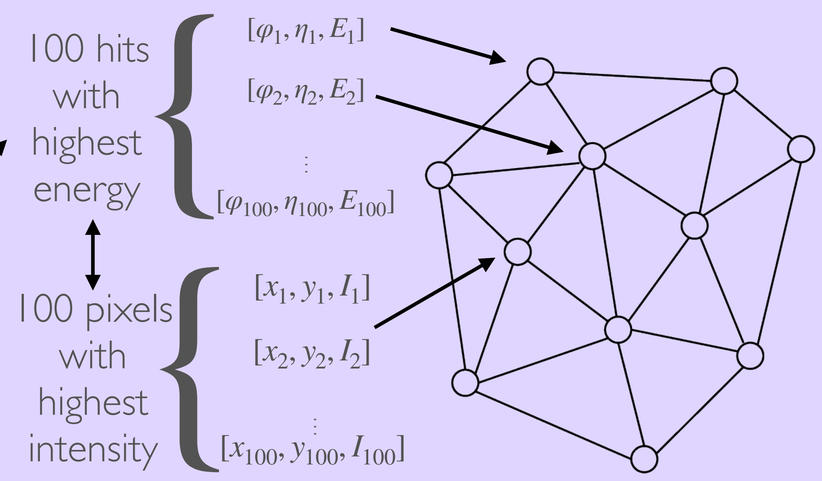
- We anticipate HL-LHC data to enter the exabyte regime (1 billion GB)
- Current rate of computational advances will not meet HL-LHC needs
- For simulation, there has been success using generative and convolutional neural networks (CNNs)

- CNNs convert the detector array data into a 3D image or matrix - this is inefficient due to sparsity of data and irregular geometry of HGCAL



- We propose Graph Neural Networks instead, where we represent detector ***hits*** as the nodes
- We thus have a network which is 1) sparse, 2) generalizable to any geometry and 3) more naturally suited to the data

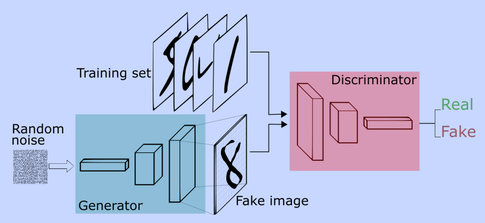
Graph Neural Networks



For ease of testing we used the **MNIST handwritten** digits dataset (right) instead and **sparsified** it to match the form of HGCAL data (up)

Generative Adversarial Networks

- The challenge was that there are no published graph generative models yet - we had to develop one
- We used generative adversarial networks as our framework



Examples of convolutional GANs in action above. Left: MNIST digits. Center: Faces. Right: ECAL detector data

Architectures and Results

Summary

- Developed a new graph GAN for faster HGCAL data generation
- It was successful on sparsified MNIST dataset
- Next step (in progress) is to apply to HGCAL data

Animations of the training process

Access this poster online

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