IMPROVING THE MULTIPLICITY GENERATOR FOR THE EMPIRICALLY TRAINED HADRONIC EVENT REGENERATOR

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OUTLINE

Background: Event Generators

\circ ETHER

• Generative Adversarial Nets

Improvements: Ensemble
 Learning and Conditional
 Feature

○ Future: Interpolation

EVENT GENERATORS

PYTHIA
 Lund String Model



http://home.thep.lu.se/~ torbjorn/Pythia.html

- Tools for experimental analysis
- Simulate hadronization processes
- Incomplete knowledge
 requires compromises
- Theory-dependent



THE EMPIRICALLY TRAINED HADRONIC EVENT REGENERATOR (ETHER)

- No "baked in" theory to govern vertex interactions
- Trained on collision event data
- Generate samples from real data distribution
- Wider applications in phenomenological investigation
- Generative Adversarial Networks (GANs)



GENERATIVE ADVERSARIAL NETWORKS [1]

- Powerful <u>unsupervised</u> model
- Adaptable
- \odot 2 neural networks
 - \bigcirc Generator
 - **Discriminator**



GENERATIVE ADVERSARIAL NETWORKS [1] <u>Generator Training Step</u> Generator update weights Z ○ Adversarial training x_{g} Discriminator ○ Alternating training steps \bigcirc *D* trained on true data probability **Discriminator Training Step** \bigcirc *G* evaluated by *D* Discriminator ○ Once fully trained, generator used independently χ_t probability update weights

ENSEMBLE LEARNING [3]

 Multiple models learning to solve the same problem
 "Bagging"

OLearn rare events faster

○ Reduce variance

 \bigcirc Parallel training

 \bigcirc Reduce training time



ENSEMBLE LEARNING





- \circ 1 GAN
 - o 100,000 event data set
 - 0 10,000 epochs
 - \circ Training time: ~5 days
 - 10,000 events generated

- \circ 10 GANs
 - o 10,000 event data sets
 - 0 10,000 epochs
 - $\odot~$ Training time for 1 GAN: ~14 hr
 - 10 x 10,000 events generated and averaged

CONDITIONAL FEATURE: CENTER OF MASS ENERGY [2]

- Event data changes as a function of energy
- Condition GAN on CoM energy
- \bigcirc Labels y and y' concatenated to inputs of D and G.
 - \bigcirc Continuous labels
 - Discrete labels
- Adds another degree of freedom







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FUTURE: INTERPOLATION

- Goal: Continuous conditional energy feature
- $\circ~$ Continuous labels
 - Preserved relationships between labels
 - \circ Conducive to interpolation
- Necessary future step in ETHER development





REFERENCES

[1] Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D.,
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 arXiv:1406.2661 [stat.ML].

[2] Mirza, M., Osindero S. (2014). Conditional Generative Adversarial Nets. arXiv:1411.1784 [cs.LG].

[3] Vadim Smolyakov, "Ensemble Learning to Improve Machine Learning Results", Medium. 2017.