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IEA-GAN: Intra-Event Aware GAN with Relational Reasoning for the Fast Detector Simulation

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A realistic detector simulation is an essential component of experimental particle physics. However, it is currently very inefficient computationally since large amounts of resources are required to produce, store, and distribute simulation data. Deep generative models allow for more cost-efficient and faster simulations. Nevertheless, generating detector responses is a highly non-trivial task as they carry fine-grained information and have correlated mutual properties within an ''event", a single readout window after the collision of particles. Thus, we propose the Intra-Event Aware GAN (IEA-GAN) and demonstrate its use in generating sensor-dependent images for the pixel vertex detector (PXD), the sub-detector with the highest spatial resolution at the Belle II Experiment. First, we show that using the domain-specific relational inductive bias introduced by our novel Relational Reasoning Module; one can approximate the concept of an event in the detector simulation. Second, we propose a Uniformity loss in order to maximize the information entropy of the discriminator's knowledge. Lastly, we develop an Intra-Event Aware loss for the generator to imitate the discriminator's dyadic class-to-class knowledge. As a result, we show that the IEA-GAN not only captures fine-grained semantic and statistical similarity among the images but also finds correlations among them. Consequently, It leads to a significant enhancement in image fidelity and diversity compared to the previous state-of-the-art models.

Author: HASHEMI, Hosein (LMU Munich)

Co-authors: Dr KAHN, James (Helmholtz AI, Karlsruhe Institute of Technology (KIT)); Dr SHARIFZADEH, Sahand (DeepMind); KUHR, Thomas (Ludwig Maximilians Universitat (DE))

Presenters: HASHEMI, Hosein (LMU Munich); Dr HARTMANN, Nikolai (LMU Munich)

Session Classification: Generative Models – Detector Level