Fast Simulation of Gamma/Proton Event Images for the TAIGA-IACT Experiment using Generative Adversarial Networks

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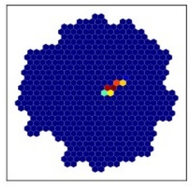
Event images

Charged cosmic rays and high energy gamma rays interact with the atmosphere.

This produces extensive air showers of secondary particles emitting Cherenkov light.

The TAIGA-IACT telescopes detect the light.



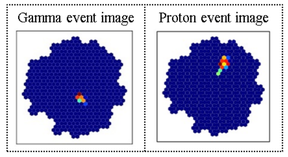
Detected data form "images" of the air shower.

The original recorded images are hexagonal.

Types of events and modelling

Two types of events are observed:

- gamma-quanta — events of interest
- hadrons - background events. Most of the observed hadronic events are proton events



Identifying the type of the registered event is an important task.

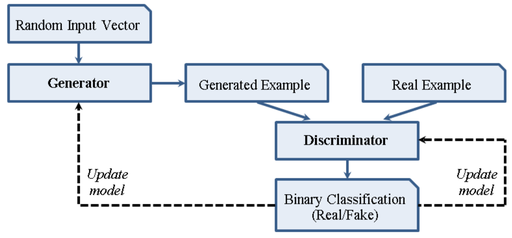
In the TAIGA-IACT project, in addition to images obtained experimentally, model images are widely used. Current modelling involves Monte Carlo simulation of the underlying physical processes. This procedure is very resource intensive and time consuming.

Our goal: to simulate event images quickly and still accurately.

We suggest using generative adversarial networks.

Generative adversarial networks (GANs)

GAN is a special class of machine learning frameworks designed to generate, improve or process images. Each GAN consists of two contesting neural networks: a generator and a discriminator.



Generator: tries to transform its random input into images similar to the real ones.

Discriminator tries to distinguish between real images and fake images produced by the generator.

Generator and discriminator are trained together on real images in an adversarial game.

Input preprocessing and GAN training

GAN training requires training images.

We choose to make a separate network for each type of event.

For training we used a sample of 2D images obtained using OPTICA-TAIGA Monte Carlo simulation software containing:

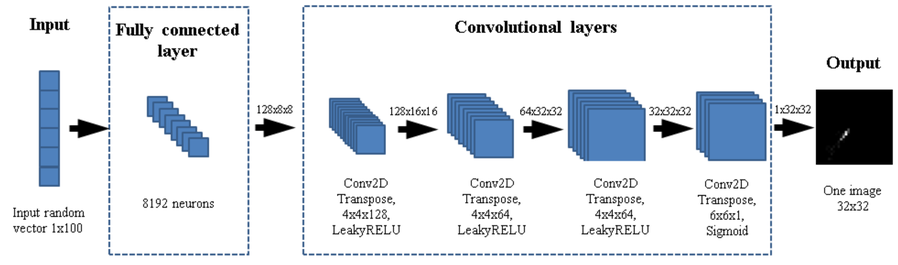
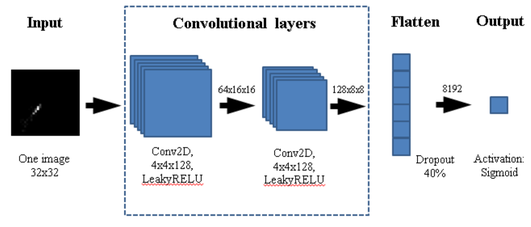
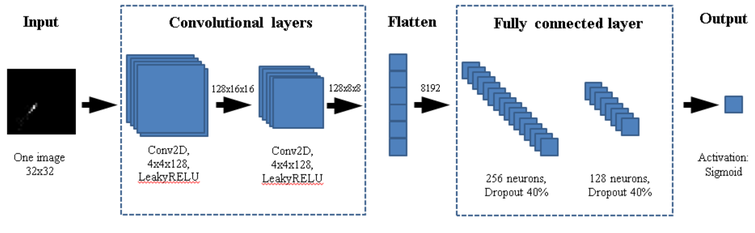
- 25000 gamma events
- 25000 proton events

When preparing the training images, we applied:

- image cleaning
- coordinate transformation
- image resizing
- pixel values recalculation

Examples of images after preprocessing:

Generator and discriminator architectures for TAIGA-IACT

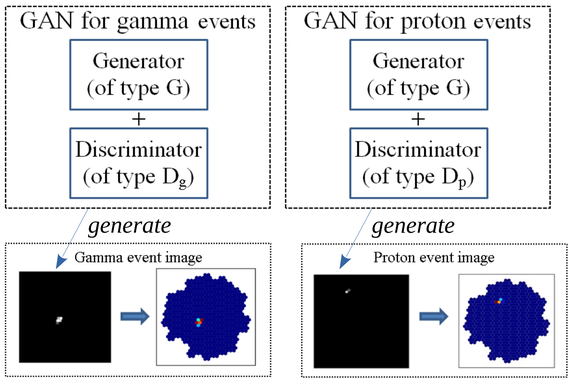
Common generator architecture for both gamma events and proton events		G
Discriminator architecture for gamma events		D_g
Discriminator architecture for proton events		D_p

Network training and results

Two separate GANs were created: for gamma events and for proton events.

A training set for each GAN: 25000 events of the corresponding type.

Network training at the GPU Tesla P100 took about 6 hours for each network.



After training, generation of 4000 events (of any type) takes about 10 seconds.

Then the generated images are converted back to hexagonal form.

Verification results:

- generated gamma events are mostly classified as gamma events
- generated proton events differ with confidence from gamma events

Conclusion

- GANs simulate proton and gamma events for the TAIGA-IACT experiment with a high degree of accuracy and reliability.
- GANs do not copy the original images, so the generated images are completely new, although they retain the statistical features of the original images.
- Most of the generated events are indistinguishable from the events generated using the traditional Monte Carlo method.
- At the same time, the rate of generation of events using GANs is much higher than the rate of generation by the Monte Carlo method.
- To ensure that the generated sample contains only correct images, all generated images must be checked by the TAIGA-IACT classification program, with inappropriate images being discarded.

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