Generative Adversarial Networks: first steps for CTA

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Gamma-ray observations: air showers

$\gamma$-ray enters the atmosphere

Electromagnetic cascade

Primary $\gamma$

c+ c- c+ c- c+ c- c+ c- c+
c+ c- c+ c- c+ c- c+ c- c+
c+ c- c+ c- c+ c- c+ c- c+

10 nanosecond snapshot

0.1 km$^2$ “light pool”, a few photons per m$^2$.

https://www.cta-observatory.org/about/how-cta-works/
Cherenkov Telescope Array

Two sites:
- Chile, Atacama desert
- La Palma, Canary Islands

Three telescope sizes:
- large (23 m, energy range 20 GeV - 150 GeV)
- medium (11 m, 150 GeV - 5 TeV)
- small (4 m, 5 TeV - 300 TeV; only in Chile)
The goal: distinguish gamma and proton showers
The issue: differences between real images and simulations

A classification algorithm can really get confused by these differences.
The issue: differences between real images and simulations

Simulated images can be classified with a high accuracy using CNNs (Etienne’s talk). But all models trained on simulated data fail on real data.

• **Expected noise features on the real images:**
  * Unknown sky background: Poisson-like noise, with mean varying over the image and with correlations
  * Independent detector noise: independent Poisson-like, with mean varying over the image
  * Artefacts from the telescope imaging: correlated shapes.
  * Blind pixels (more or less stable over time).
  * Hot pixels.

• **Plus, the real events do not always look like the simulated events:**
  * Small parameter space of the simulations.
  * Varying atmospheric conditions.
  * Etc…

So a solution could be to learn how to augment the simulated data to match real data.
Solution: a Generative Adversarial Network (GAN)?

**Generator**: usually a Convolutional Neural Network (CNN)
Tries to transform its random input into images similar to the real ones

**Discriminator**: also a CNN
Tries to distinguish between real images and those produced by the generator
Solution: a Generative Adversarial Network (GAN)?

Nguyen et al., 2017
Solution: a Generative Adversarial Network (GAN)?
Real images: To create “real images”, I added noise to simulated images.
The product of a GAN

- Generator should be far better tuned, probably more complex.
- The procedure might require much longer training than was mine.
- Independent Poisson noise may be hard to imitate for a CNN: internally, it uses (among others) lots of weighted sums of the input pixels, so tends to smooth out noise.
- The GAN is better suited to learn patterns: diffuse uneven background, artefacts from the imaging system - should be tried out
- Extension of the simulated parameter space by the GAN raises the question of class: how to prevent the GAN to distort proton events into gamma events?
Further possibilities

* Auxiliary classifier GAN (Odena et al, 2017)

monarch butterfly  goldfinch  daisy  redshank  grey whale
Further possibilities

* Auxiliary classifier GAN (Odena et al, 2017)

* Neural style transfer (Gatys et al., 2015)
Thank you for all, during all these years!

And now…