Generative Adversarial Networks

Generating content, Deep Learning style

Victor ADASCALITEI

Publications

Progressive Growing of GANs for Improved Quality, Stability, and Variation

We describe a new training methodology for generative adversarial networks. The key idea is to grow both the generator and discriminator progressively: starting from a low resolution, we add new layers that model increasingly fine details as training progresses. This both speeds the training up and greatly stabilizes it, allowing us to produce images of unprecedented quality, e.g., CelebA images at 1024^2. We also propose a simple way to increase the variation in generated images, and achieve a record inception score of 8.80 in unsupervised CIFAR10. Additionally, we describe several implementation details that are important for discouraging unhealthy competition between the generator and discriminator. Finally, we suggest a new metric for evaluating GAN results, both in terms of image quality and variation. As an additional contribution, we construct a higher-quality version of the CelebA dataset.

Authors: Tero Karras
Timo Aila
Samuli Laine
Jaakko Lehtinen (NVIDIA and Aalto University)

More usages ...

Blending high resolution images

[1]

Text to image synthesis

[2]

Image completion

[3]

[3.2]

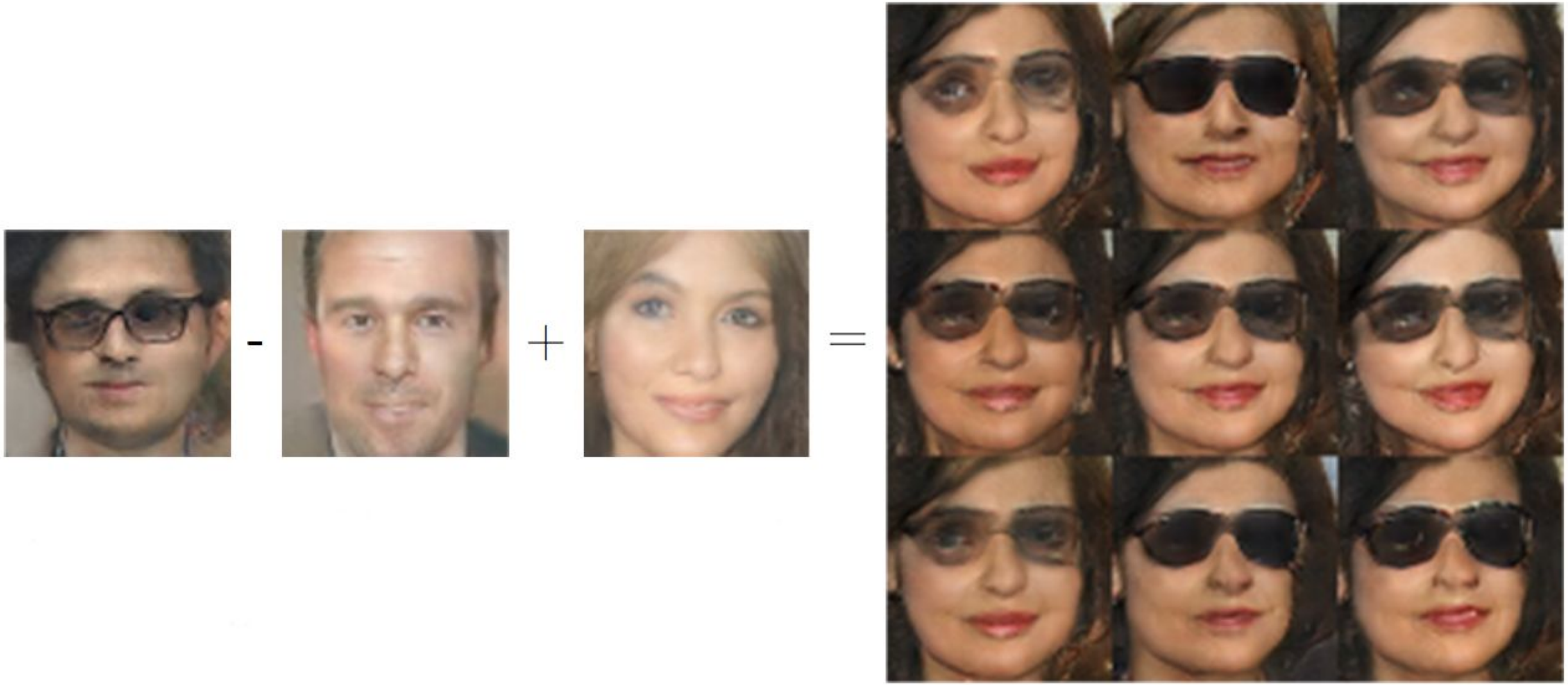
Generating videos

[4]

Image to image translations

[5]

Vector Space Arithmetic



[6]

Retail item generation

[7]

What are some recent and potentially upcoming breakthroughs in deep learning?

Yann LeCun, Director of AI Research at Facebook and Professor at NYU

Answered Jul 28, 2016 · Upvoted by Joaquin Quiñonero Candela, studied Machine Learning and Gokul Krishnan, M.Sc Computer Science & Machine Learning, ETH Zurich (2018)

There are many interesting recent development in deep learning, probably too many for me to describe them all here. But there are a few ideas that caught my attention enough for me to get personally involved in research projects.

The most important one, in my opinion, is adversarial training (also called GAN for Generative Adversarial Networks). This is an idea that was originally proposed by Ian Goodfellow when he was a student with Yoshua Bengio at the University of Montreal (he since moved to Google Brain and recently to OpenAI).

This, and the variations that are now being proposed is the most interesting idea in the last 10 years in ML, in my opinion.

Quora [8]

What are GANs?

What are GANs?

How do we say if something is part of a group or not?

Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```

Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```

Can 1 be part of this set?

Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```

Can 1 be part of this set?

How about 15?

Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```

Can 1 be part of this set?

How about 15?

… or 24?

Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```

Can 1 be part of this set?

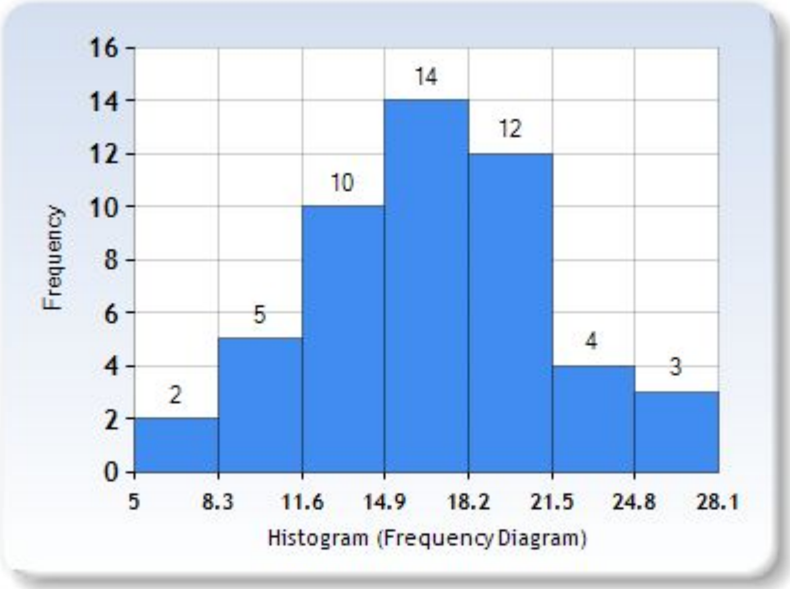
How about 15?

… or 24?

Is 15 more likely to be in this set compared to 24?

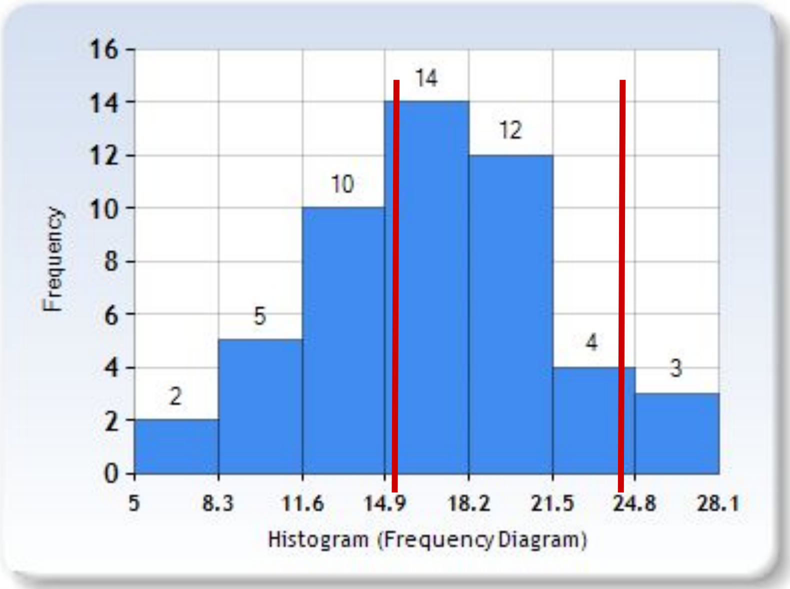
Eg.

26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148, 9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108, 5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561, 8.681153, 8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493, 5.676766, 16.448069, 17.550310, 18.291067



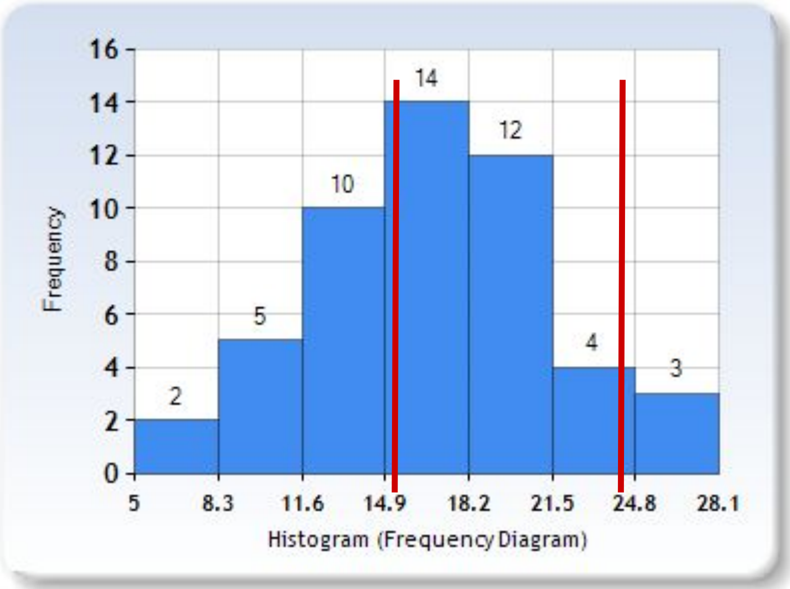
Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```



Eg.

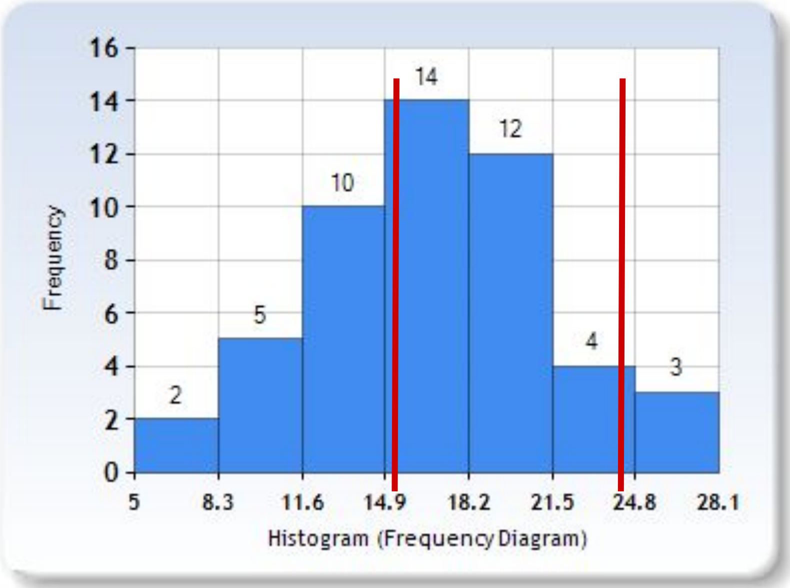
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148, 9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108, 5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561, 8.681153, 8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493, 5.676766, 16.448069, 17.550310, 18.291067



Is 15 more likely to be in this set compared to 24?

Eg.

```
26.784374, 16.221426, 23.969908, 18.128964, 13.310599,
16.169977, 10.518126, 19.088016, 11.662497, 12.075612,
18.459770, 16.673500, 18.325148,  9.600440, 22.215492,
18.303797, 16.037155, 20.368163, 16.665176, 13.573404,
15.139798, 16.515108,  5.441134, 13.283509, 16.787477,
18.294751, 25.165056, 16.328220, 12.926385, 20.027098,
14.360396, 15.171232, 13.447607, 20.654171, 20.809167,
22.041561,  8.681153,  8.919257, 21.681817, 14.043993,
20.389758, 11.593847, 15.781812, 25.418625, 21.020760,
12.751493,  5.676766, 16.448069, 17.550310, 18.291067
```



Is 15 more likely to be in this set compared to 24?

YES!

Is 15 more likely to be in this set compared to 24?

Eg.

Is **x** more likely to be in this set compared to **y**?

How to determine this?

Is **x** more likely to be in this set compared to **y**?

How to determine this?

Is x more likely to be in this set compared to y?

How to generate plausible candidates for this?

How to determine this?

Is **x** more likely to be in this set compared to **y**?

How to generate plausible candidates for this?

$x \rightarrow$ Neural Network $\rightarrow p(x) \in$ Set

$y \rightarrow$ Neural Network $\rightarrow p(y) \in$ Set

$p(x)$ **?** $p(y)$

How to determine this?

Is x more likely to be in this set compared to y?

How to generate plausible candidates for this?

How to determine this?

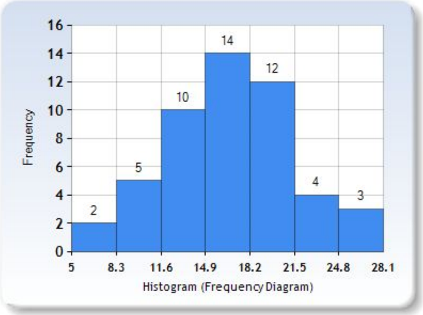
Is x more likely to be in this set compared to y?

How to generate plausible candidates for this?

How to determine this?

Is x more likely to be in this set compared to y?

How to generate plausible candidates for this?

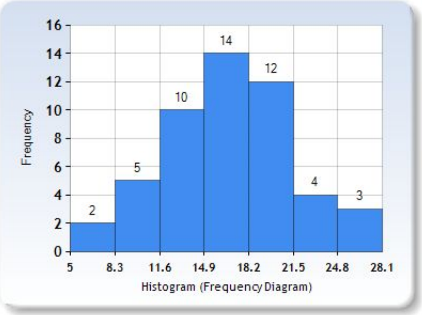


How to determine this?

Is **x** more likely to be in this set compared to **y**?

How to generate plausible candidates for this?

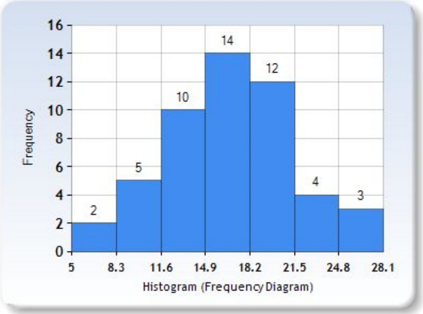
Normal Distribution with mean 16 and standard deviation of 5.



How to determine this?

Is **x** more likely to be in this set compared to **y**?

How to generate plausible candidates for this?



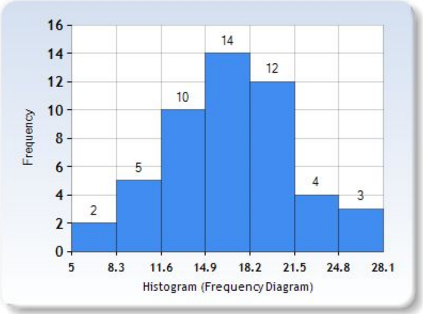
Normal Distribution with mean 16 and standard deviation of 5.

What is the data distribution function?

How to determine this?

Is **x** more likely to be in this set compared to **y**?

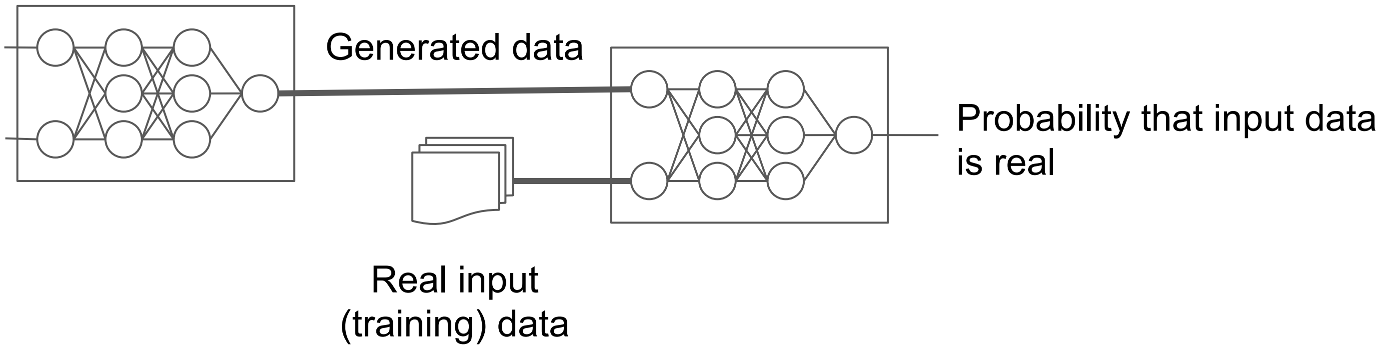
How to generate plausible candidates for this?



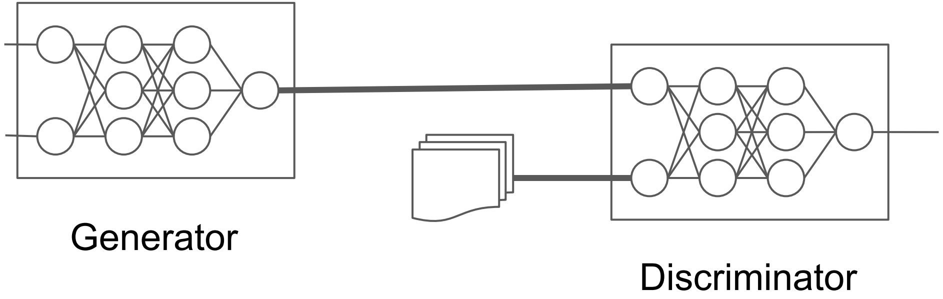
Normal Distribution with mean 16 and standard deviation of 5.

What is the data distribution function *so that we can sample new values*?

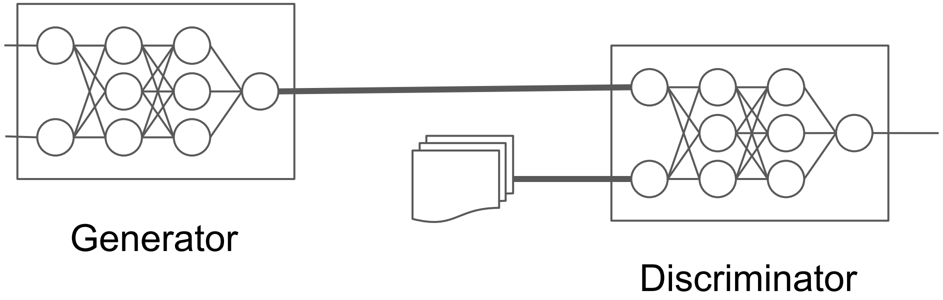
Architecture. Generating new data



Architecture. Generating new data

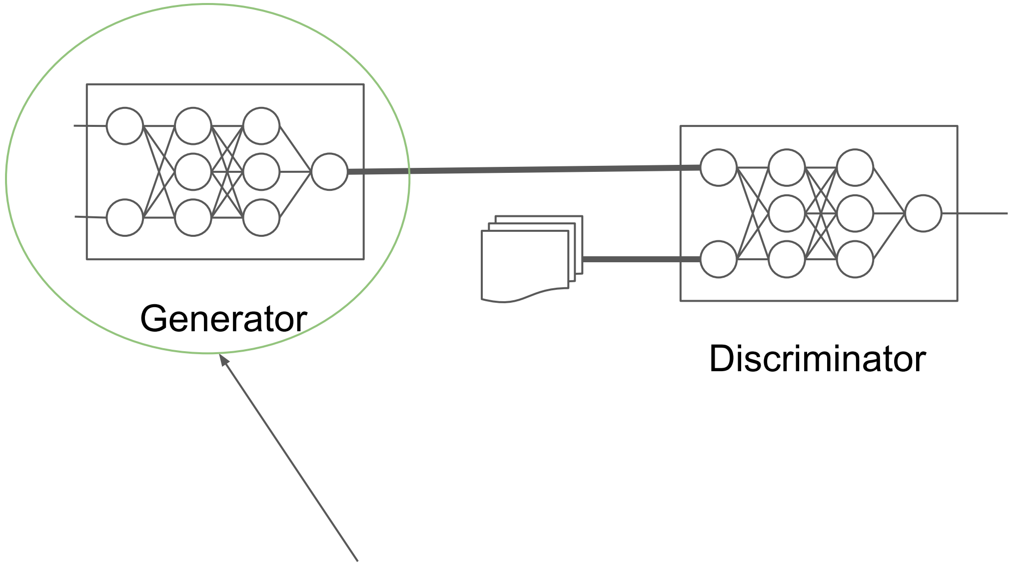


Architecture. Generating new data



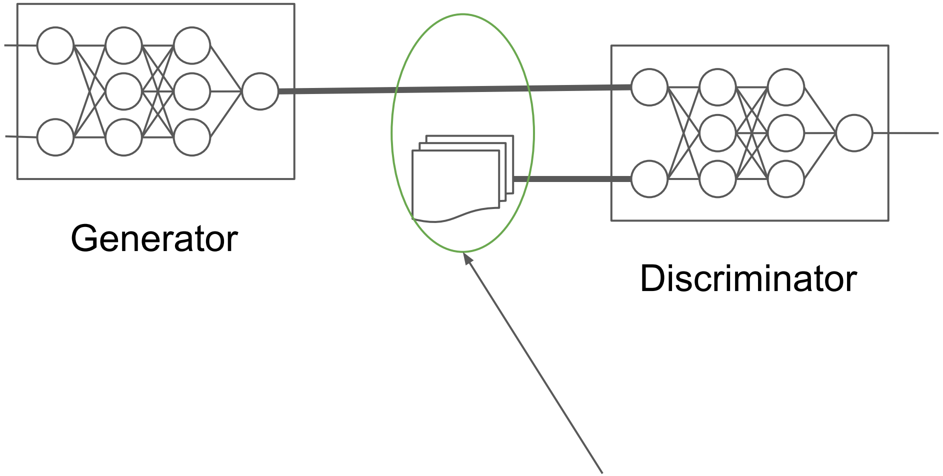
Generative Adversarial Network (GAN)

Architecture. Generating new data



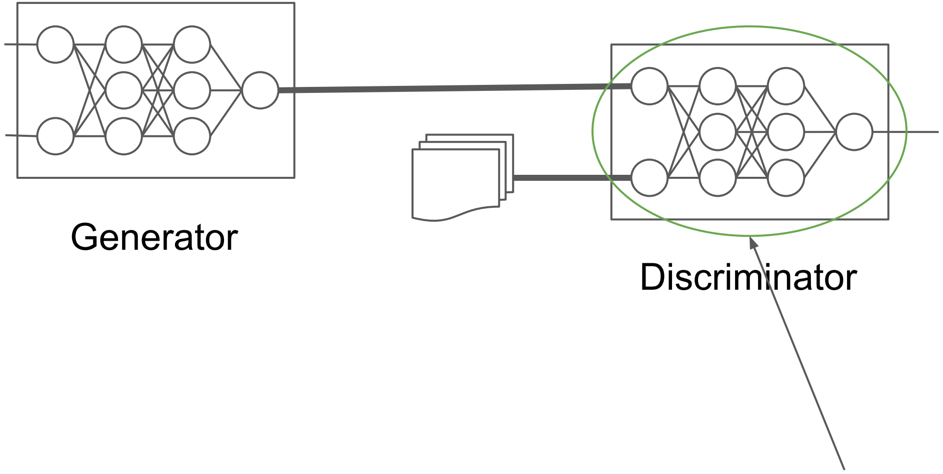
Generative Adversarial Network (GAN)

Architecture. Generating new data



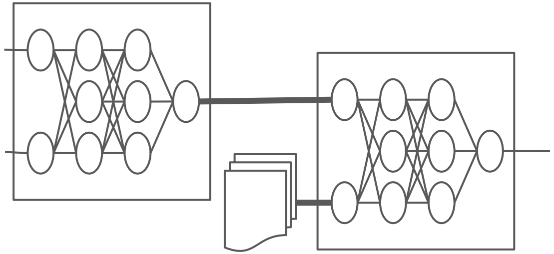
Generative **Adversarial** Network (GAN)

Architecture. Generating new data



Generative Adversarial **Network** (GAN)

GANs. Training. Cost function

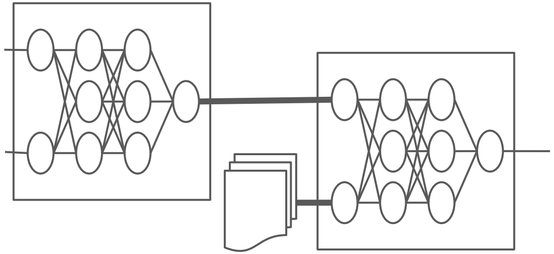


Use SGD-like algorithm of choice on two minibatches **simultaneously**:

A minibatch of training examples

A minibatch of generated samples

GANs. Training. Cost function



Use SGD-like algorithm of choice on two minibatches simultaneously:

A minibatch of **training examples**

A minibatch of **generated samples**

$$J^{(D)} = -\frac{1}{2}\mathbb{E}_{\boldsymbol{x}\sim p_{\text{data}}} \log D(\boldsymbol{x}) - \frac{1}{2}\mathbb{E}_{\boldsymbol{z}} \log\left(1 - D\left(G(\boldsymbol{z})\right)\right)$$

$$J^{(G)} = -J^{(D)}$$

[9]

Code example

Google Research Blog

The latest news from Research at Google

TFGAN: A Lightweight Library for Generative Adversarial Networks

Tuesday, December 12, 2017

Sources

[1] “GP-GAN: Towards Realistic High-Resolution Image Blending” -- Huikai et al.
https://arxiv.org/pdf/1703.07195.pdf

[2] “Generative Adversarial Text to Image Synthesis” -- Reed et al.
https://arxiv.org/pdf/1605.05396.pdf

[3] “Globally and Locally Consistent Image Completion” -- Satoshi et al.
http://hi.cs.waseda.ac.jp/~iizuka/projects/completion/data/completion_sig2017.pdf

[3.2] “Semantic Image Inpainting with Deep Generative Models” -- Yeh et al.
https://arxiv.org/pdf/1607.07539.pdf

Sources (2)

[4] “Generating Videos with Scene Dynamics” -- Vondrick et al.
http://carlvondrick.com/tinyvideo/paper.pdf

[5] “Unsupervised Image-to-Image Translation Networks” -- Ming-Yu et al.
https://arxiv.org/pdf/1703.00848.pdf

[6] “UNSUPERVISED REPRESENTATION LEARNING WITH DEEP CONVOLUTIONAL GENERATIVE ADVERSARIAL NETWORKS” -- Radford et al.
https://arxiv.org/pdf/1511.06434.pdf

[7] “Artificial intelligence can say yes to the dress” -- Quartz article
https://qz.com/1090267/artificial-intelligence-can-now-show-you-how-those-pants-will-fit/

Sources (3)

[8] Yann LeCun's Quora answer -- https://goo.gl/qS88pA

[9] "Generative Adversarial Nets" -- Ian Goodfellow et al.
http://papers.nips.cc/paper/5423-generative-adversarial-nets.pdf