

# Generative Models

# Logistics

- Project status videos: next Thursday. Instructions [on website](#).
- Next reading/video/discussion will be on Bias and Fairness
- Next:
  - Sequence modeling redux (translation, Transformers architecture, etc.)
  - Other human-centered concerns (transparency / interpretability)
  - Reinforcement Learning
- Breadth or depth (in what topics?)

# Links to have open

- [GANSpace](#)
- [GAN Lab](#)
- [GANpaint](#)
- <https://j.mp/cam2head>





# Which was real?

- First slide: FFHQ dataset (<https://github.com/NVLabs/ffhq-dataset>)
- Second slide: mid-training snapshot of fine-tuning StyleGAN2

# Today: Generation

- One approach: LMs.
- Today: alternatives
- Applications examples: [HAI-GEN workshop](#)
  - Platform game level generation
  - 3D animal shapes
  - Controlling an instrument with your voice [g.co/tonetransfer](https://github.com/tonetransfer)
  - Generating documentation for Jupyter notebooks

HAI-GEN Workshop at IUI 2021

2nd Workshop on Human-AI Co-Creation with Generative Models

# This **Artwork** Does Not Exist

Using generative adversarial networks (GAN), we can learn how to create realistic-looking fake versions of almost anything, as shown by this collection of sites that have sprung up in the past month. Learn [how it works](#).



## This Person Does Not Exist

The site that started it all, with the name that says it all. Created using a style-based generative adversarial network (StyleGAN), this website had the tech community buzzing with excitement and intrigue and inspired many more sites.

Created by Phillip Wang.



## This Cat Does Not Exist

These purr-fect GAN-made cats will freshen your feeline-gs and make you wish you could reach through your screen and cuddle them. Once in a while the cats have visual deformities due to imperfections in the model – beware, they can cause nightmares.

Created by Ryan Hoover.



## This Rental Does Not Exist

Why bother trying to look for the perfect home when you can create one instead? Just find a listing you like, buy some land, build it, and then enjoy the rest of your life.

Created by Christopher Schmidt.

<https://thisxdoesnotexist.com/>

# How might an AI *generate* an image?

- ask a pretrained model : what's the ideal "eye"/"face"  
"collage" existing images

DeepDream

# Goal: *Why* can generative models work?

- How? Look on YouTube
- What about the world makes this work?

# Main Ideas Today

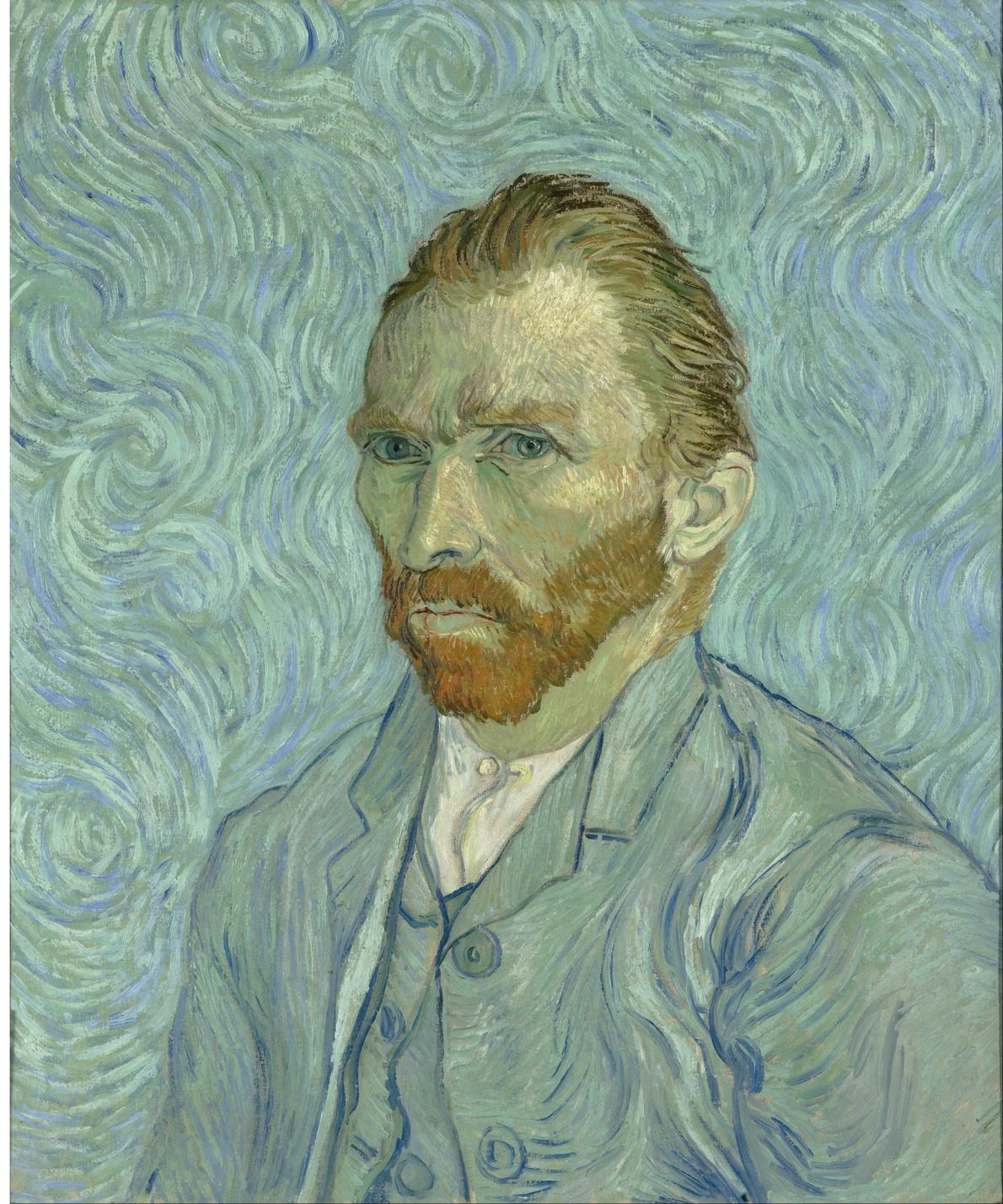
- We can give *probabilities* to images / sounds / videos / ...
- Natural images occupy a tiny portion of the space of all images.
- We can map that small portion to a *latent space*.
- Generative models consist of some combination of:
  - **generator / decoder**: latent space -> full image
  - **encoder**: image -> latent space
  - **discriminator**: image -> probability

How likely is this image?

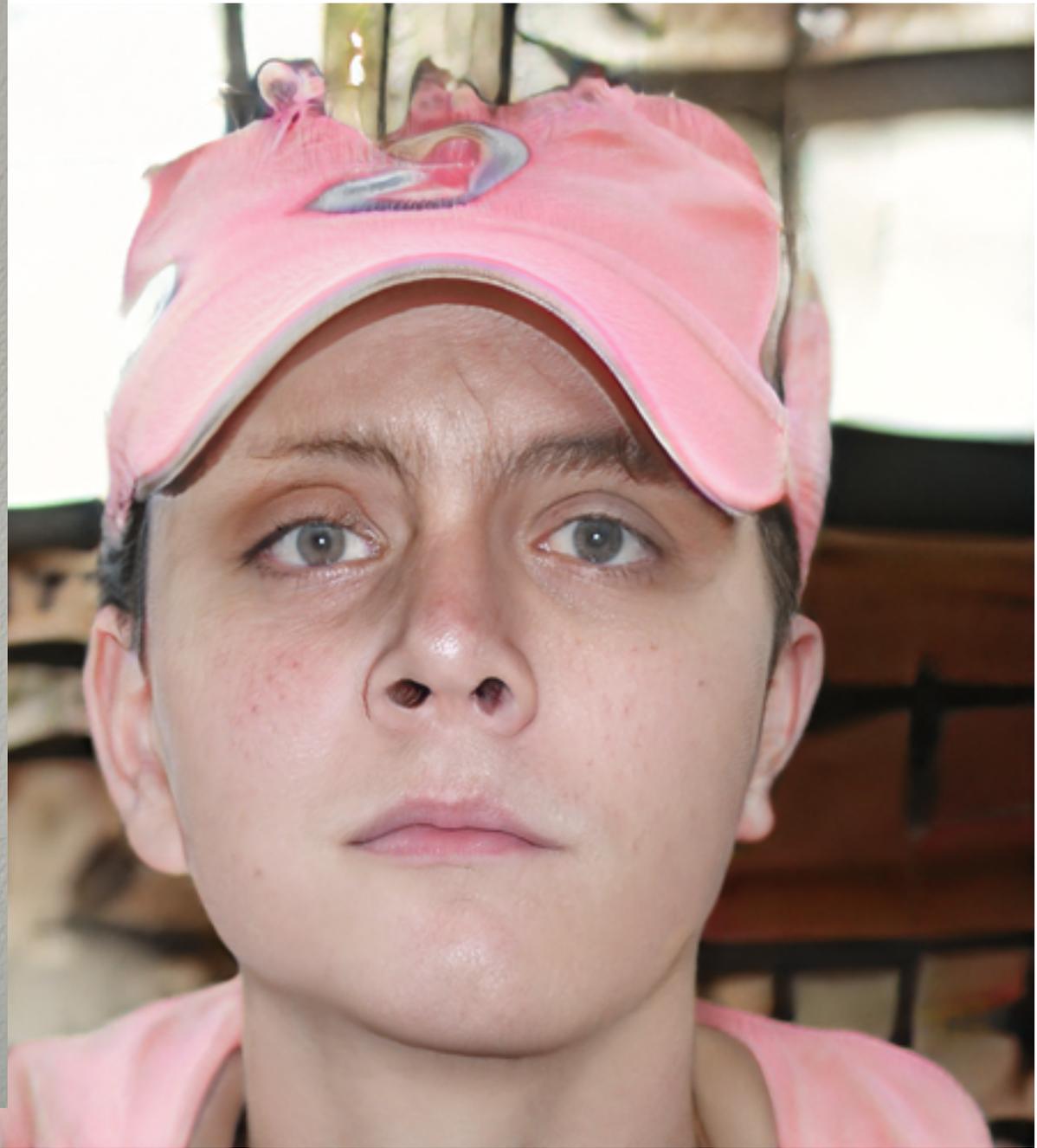


[https://commons.wikimedia.org/wiki/File:Lauffen\\_a.N.\\_-\\_die\\_Regiswindiskirche\\_auf\\_ihrem\\_Felsen\\_%C3%BCber\\_dem\\_Neckar\\_2.jpg](https://commons.wikimedia.org/wiki/File:Lauffen_a.N._-_die_Regiswindiskirche_auf_ihrem_Felsen_%C3%BCber_dem_Neckar_2.jpg)

How likely is this image?



[https://commons.wikimedia.org/wiki/File:Vincent\\_van\\_Gogh\\_-\\_Self-Portrait\\_-\\_Google\\_Art\\_Project.jpg](https://commons.wikimedia.org/wiki/File:Vincent_van_Gogh_-_Self-Portrait_-_Google_Art_Project.jpg)



How li

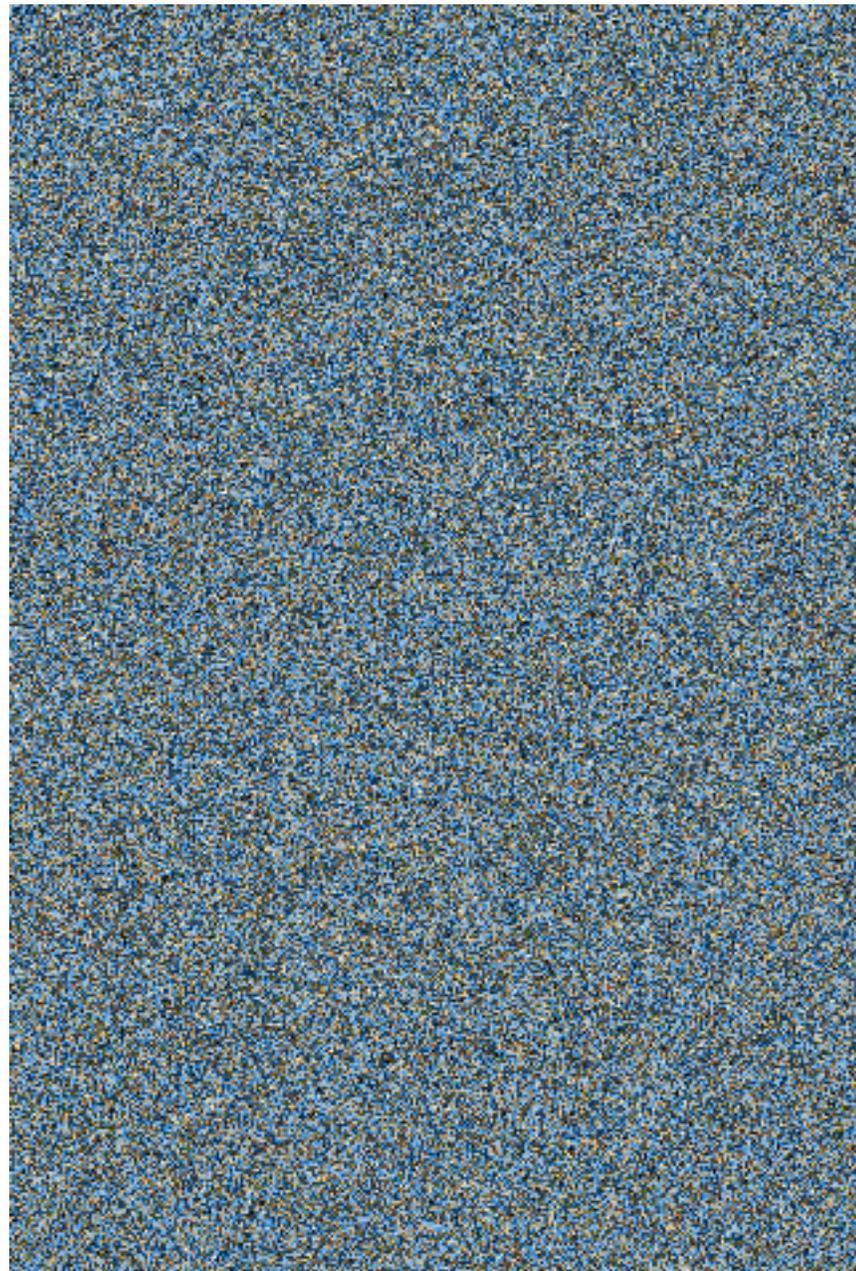


<https://www.highlights.com/parents/articles/inside-high-five-october-2018-thats-silly>

How



?



# We can give a probability to an image

- **Often:** probability that the image is *real*
- Occasionally: probability that a given image is this one

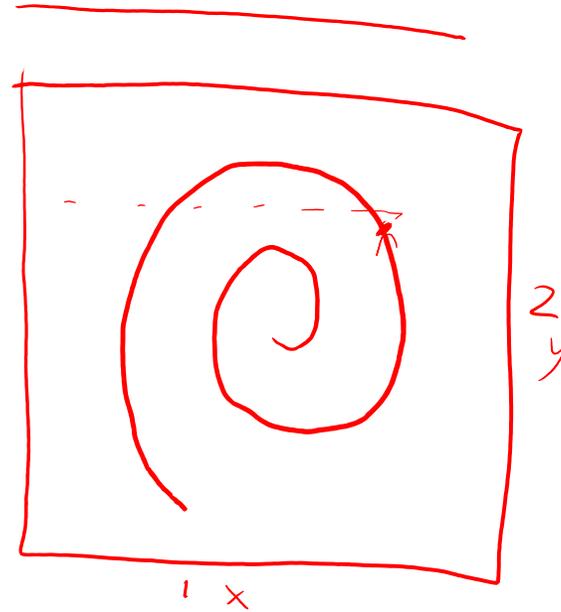
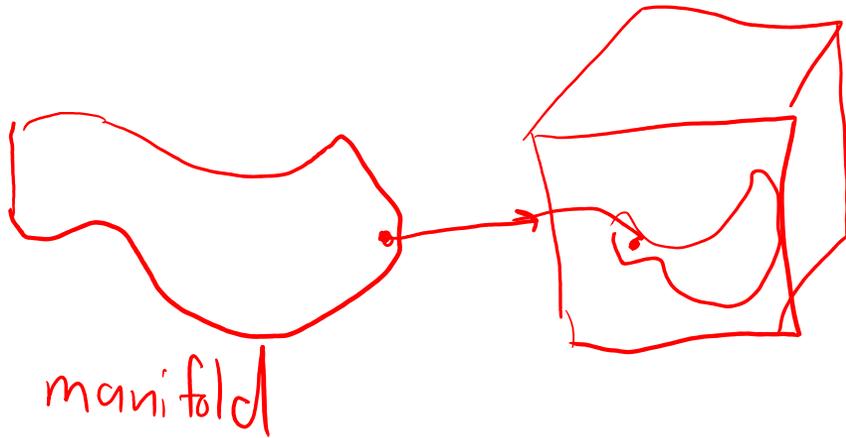
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# Natural images are a small subset of all possible images

$$12M \times 3$$

$$36M \times 256 = \sim 10B$$



intrinsic dimensionality = 1

Core idea: *embed* images in latent space

- Demo: <https://observablehq.com/@stwind/latent-flowers-garden>

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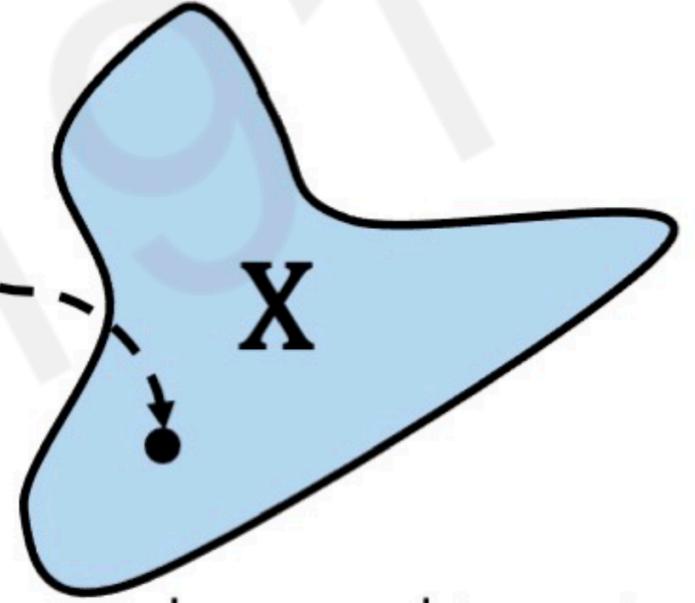
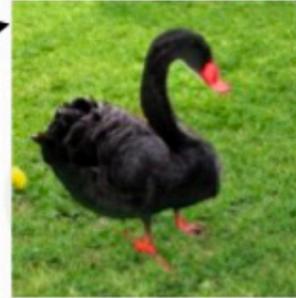
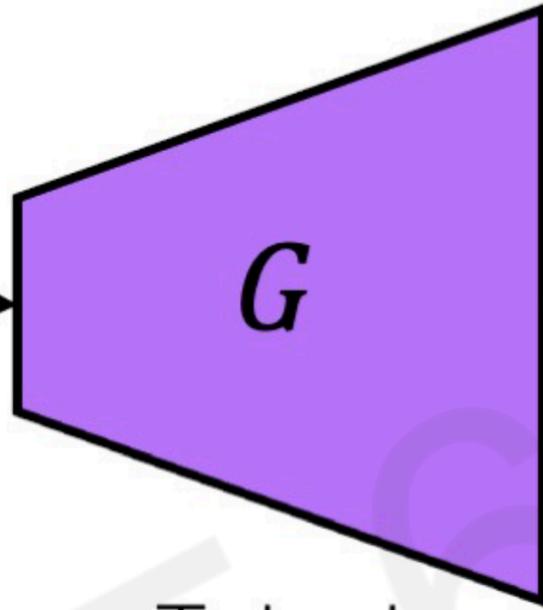
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# Examples of Generative Models

# Generative Adversarial Network

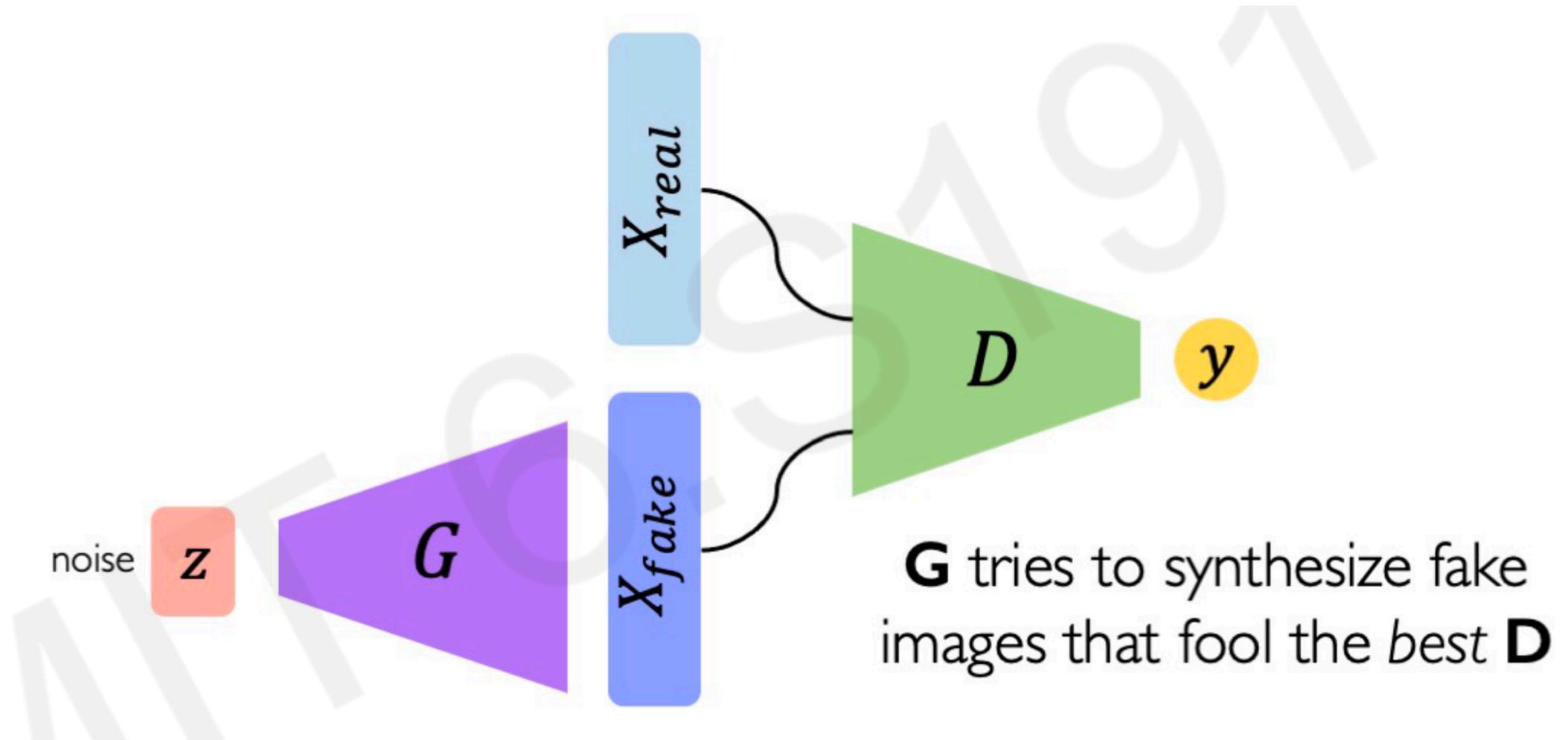
Gaussian noise  
 $z \sim N(0,1)$



Trained  
generator

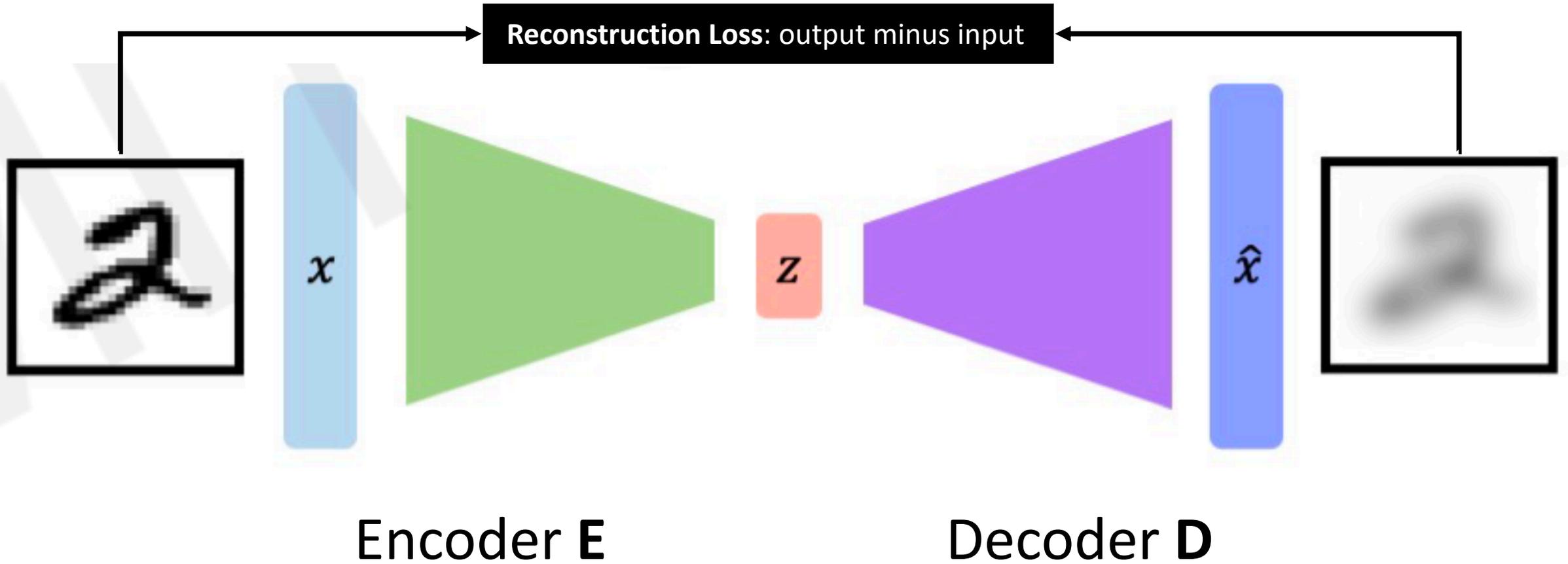
Learned target  
data distribution

# Generative Adversarial Network

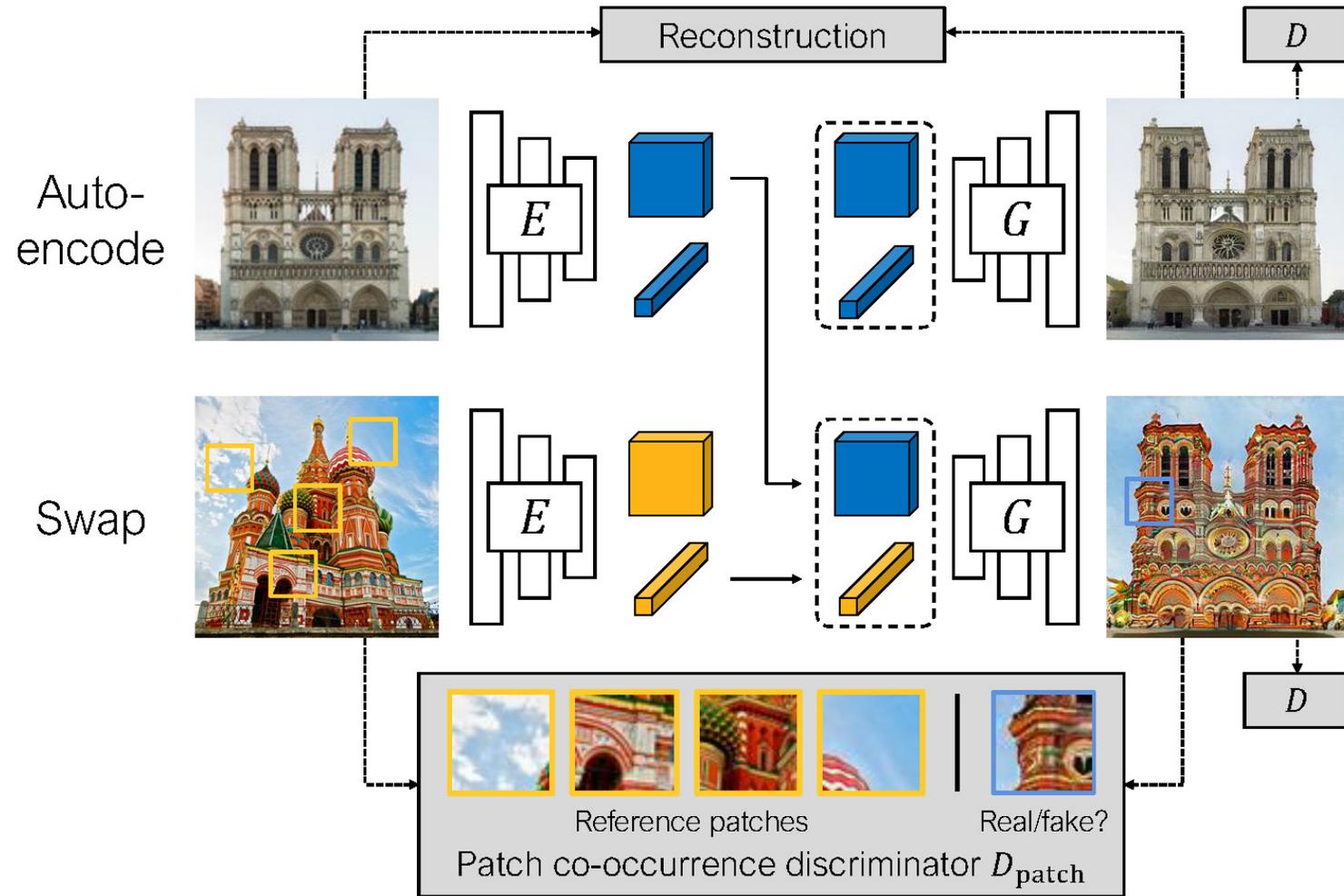


Try it at [GANLab](#)

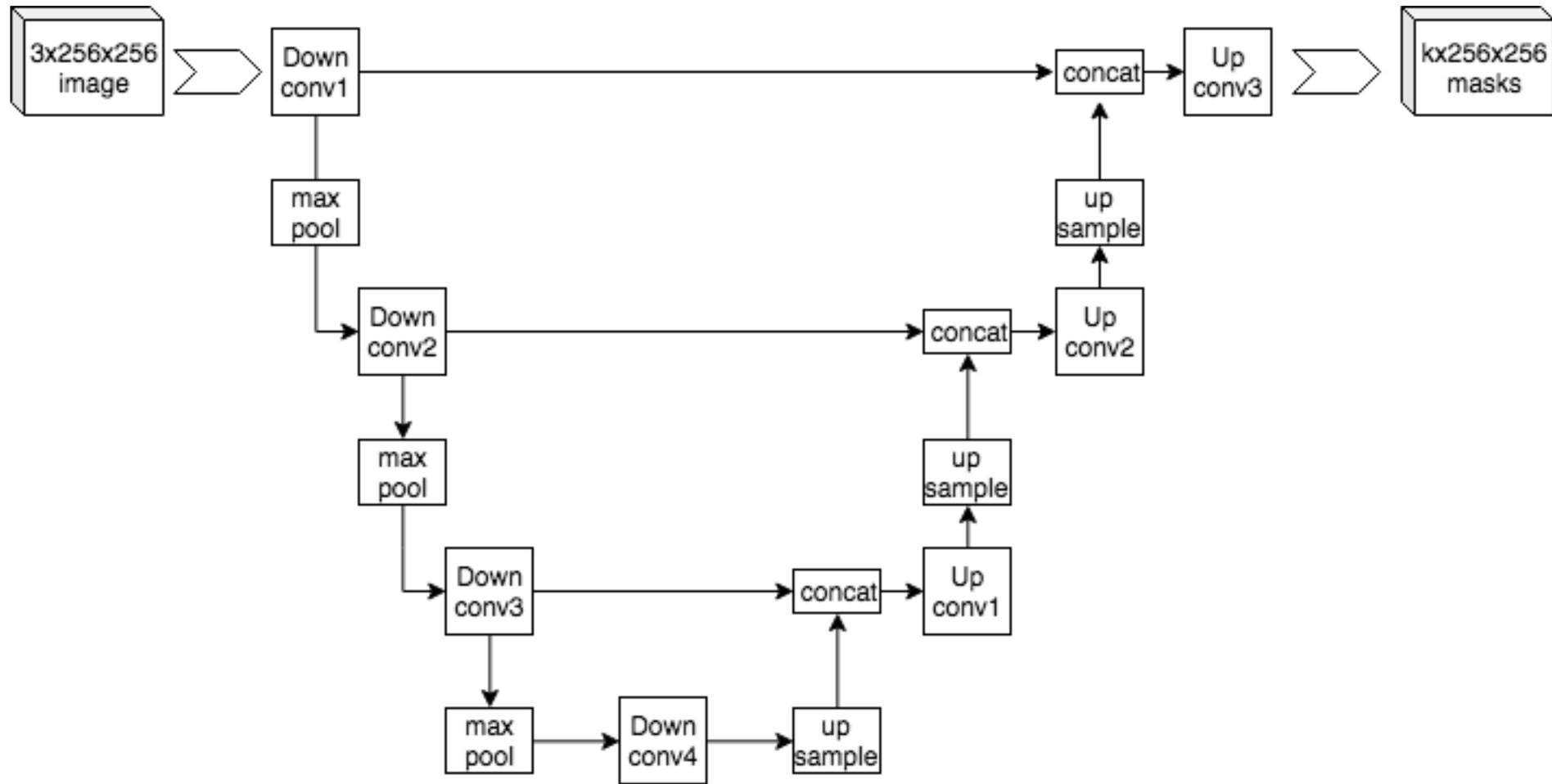
# Autoencoder



# Swapping Autoencoder



# U-Net



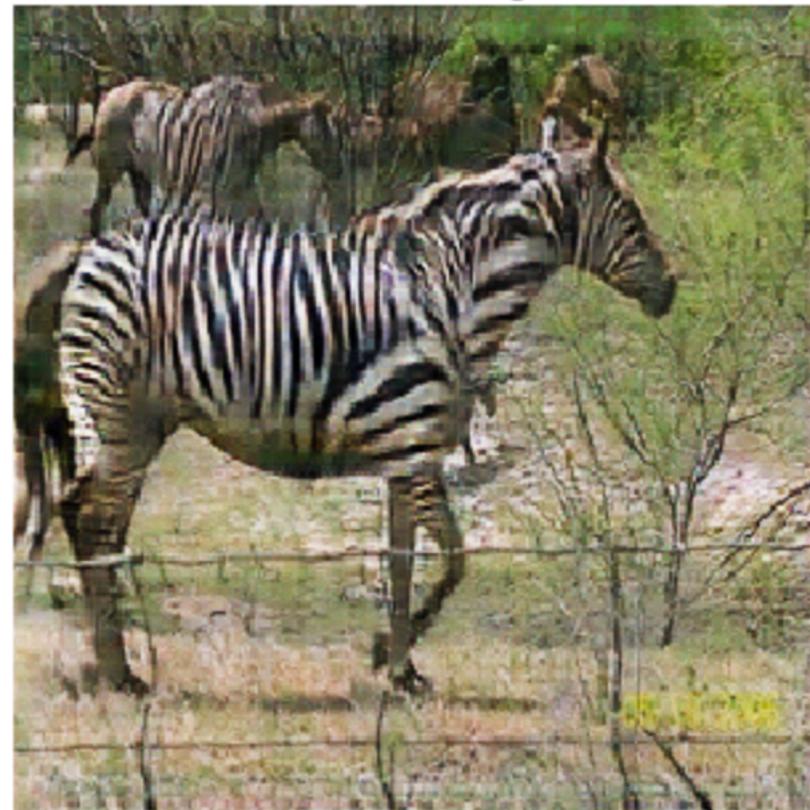
[https://commons.wikimedia.org/wiki/File:Example\\_architecture\\_of\\_U-Net\\_for\\_producing\\_k\\_256-by-256\\_image\\_masks\\_for\\_a\\_256-by-256\\_RGB\\_image.png](https://commons.wikimedia.org/wiki/File:Example_architecture_of_U-Net_for_producing_k_256-by-256_image_masks_for_a_256-by-256_RGB_image.png)

# CycleGAN (image $\leftrightarrow$ image)

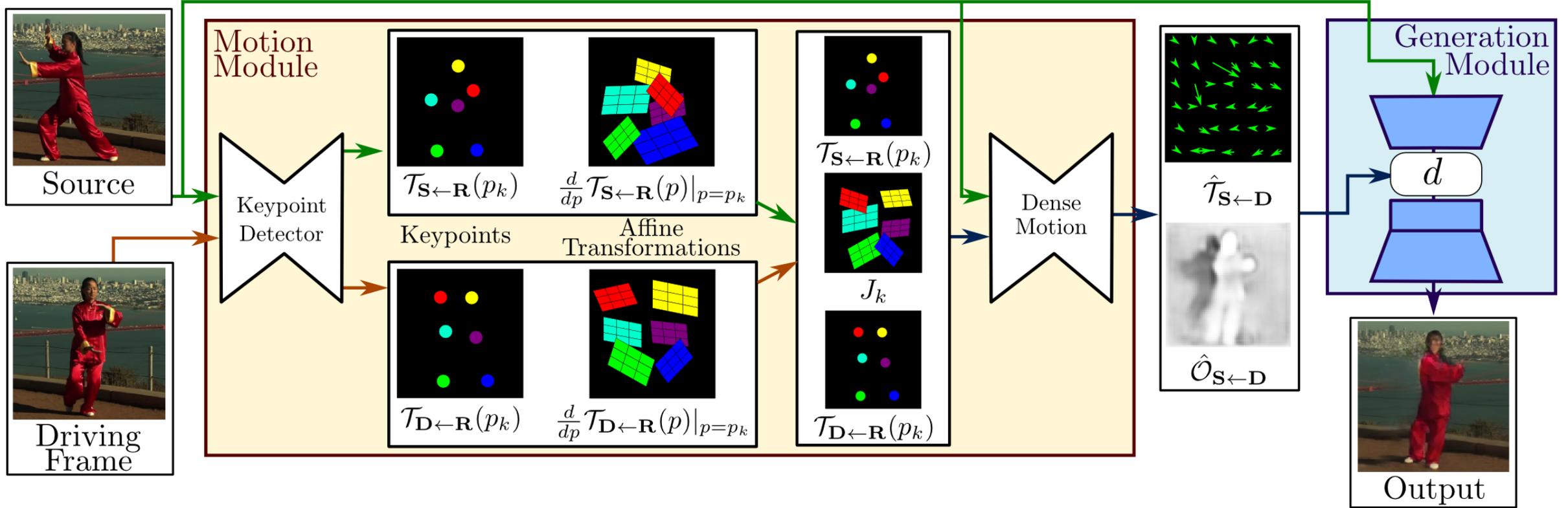
Input Image



Predicted Image

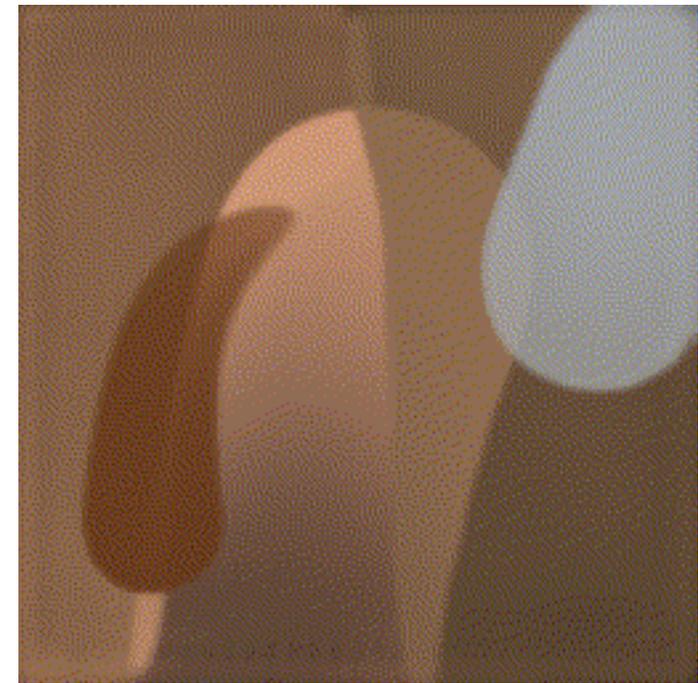


# You don't need all this for a simple deepfake



# Many other creative approaches

- Learning to draw an image stroke-by-stroke
  - PaintBot / <https://arxiv.org/abs/1904.02201>
  - Model-based RL: <https://arxiv.org/abs/1903.04411>
- Interactive image editing (GANPaint)
- Controls (e.g., [GANSpace](#))
- Use a sequence model (Transformers)
  - <https://compvis.github.io/taming-transformers/>
- Neural Rendering (NeRF)
  - <https://github.com/Kai-46/nerfplusplus>
  - <https://github.com/yenchenlin/awesome-NeRF>



# Applications

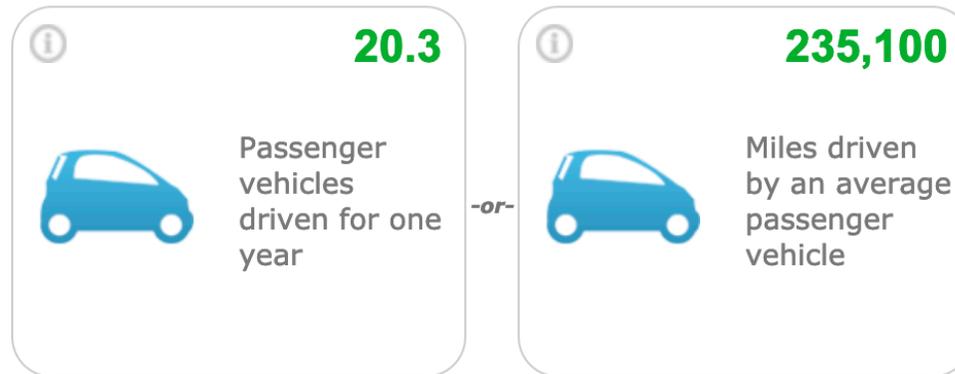
- Video conferencing
  - Background segmentation (e.g., virtual backgrounds)
  - regenerate the face on the client side (e.g., [NVIDIA Maxine](#))
- Sim2real: train robots in simulations that perform well in real world
- Super-resolution, image/sound restoration
- Inpainting: remove distracting objects (now in Photoshop)
- Anomaly detection (e.g., tumor detection)
- Causal inference

# Perspectives and Ethical Considerations

# StyleGAN2's Energy Cost

The entire project, including all exploration, consumed 132 MWh of electricity, of which 0.68 MWh went into training the final FFHQ model. In total, we used about 51 single-GPU years of computation (Volta class GPU). A more detailed discussion is available in Appendix **F**.

## Greenhouse gas emissions from

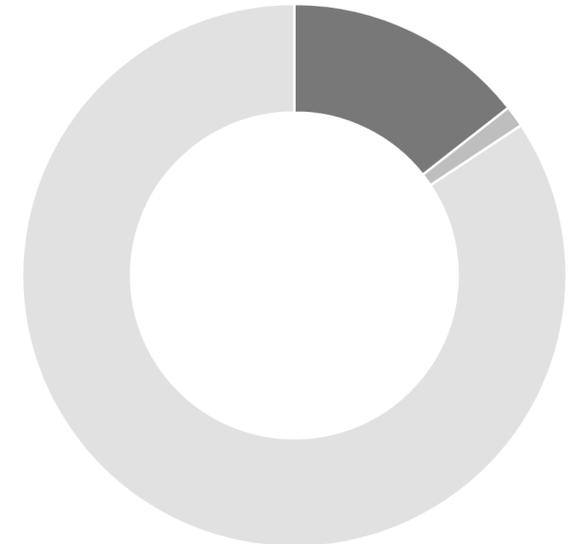


# This Black Woman Does Not Exist

Below you see the first three “black” women generated in that session by StyleGAN, and one randomly selected “white” woman from the same session for comparison. The first image is less detailed, the following images is highly distorted; the final image (and notably a small variation of the other) is somewhat convincing, but unflattering.



■ White Women  
■ Black Women  
■ Other



<https://www.intersectsy.com/intersectsy/2019/10/3/what-i-learned-about-bias-from-the-first-ai-generated-faces-on-wikimedia-commons>

# Adversarial *Examples*

- Generating an image to fool a classifier

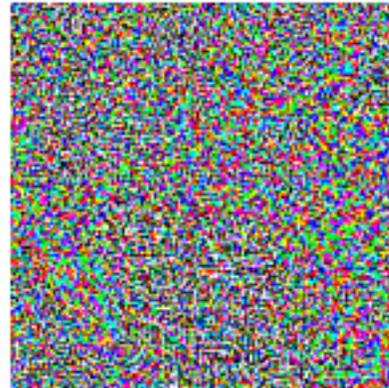


$x$

“panda”

57.7% confidence

+ .007 ×



$\text{sign}(\nabla_x J(\theta, x, y))$

“nematode”

8.2% confidence

=



$x + \epsilon \text{sign}(\nabla_x J(\theta, x, y))$

“gibbon”

99.3 % confidence

Who owns the image? Who owns the model?

Other questions?