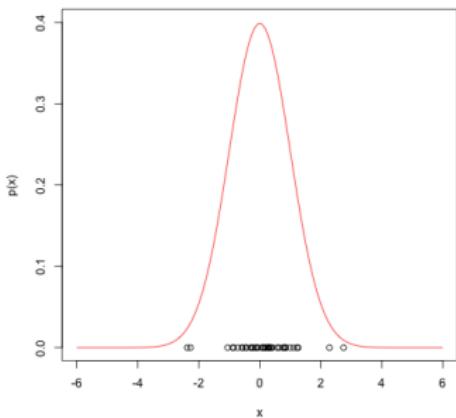


# Deep Learning

## Introduction to Generative Models



### Learning goals

- learning a generative model
- examples of generative models

# WHICH FACE IS FAKE?



Fake faces generated by [ThisPersonDoesNotExist.com](https://ThisPersonDoesNotExist.com). | Image: The Verge

# DEEP UNSUPERVISED LEARNING

There are two main goals of **deep unsupervised learning**:

- **Representation Learning**

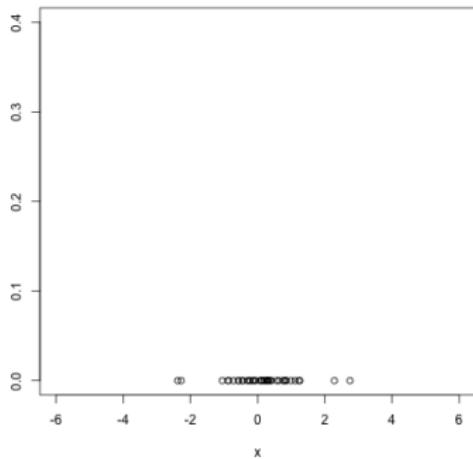
- Examples are: manifold learning, feature learning, etc.
- Can be done by an autoencoder
- Examples of applications:
  - dimensionality reduction / data compression
  - transfer learning / semi-supervised learning

- **Generative Models**

- Given a training set  $\mathcal{D} = (\mathbf{x}^{(1)}, \dots, \mathbf{x}^{(n)})$  where each  $\mathbf{x}^{(i)} \sim \mathbb{P}_x$ , the goal is to estimate  $\mathbb{P}_x$ .
- **Goal:** Take as input training samples from some distribution and learn a model that represents that distribution!
- Examples of applications:
  - generating music, videos, volumetric models for 3D printing, synthetic data for learning algorithms, outlier identification, images denoising, inpainting, etc.

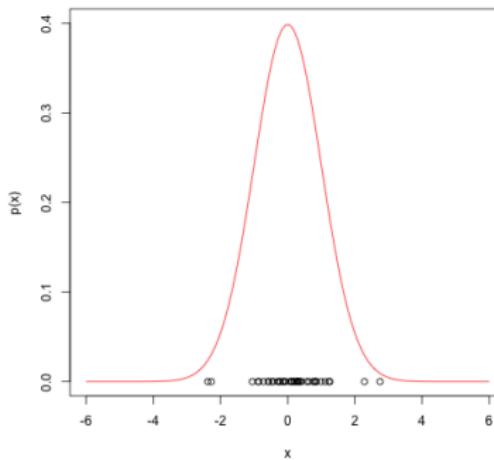
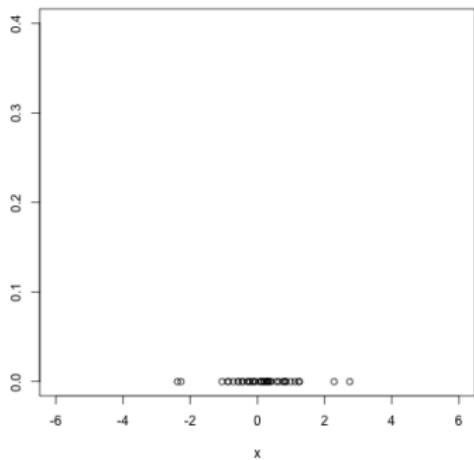
# DENSITY FITTING / LEARNING A GENERATIVE MODEL

Given  $\mathcal{D} = (\mathbf{x}^{(1)}, \mathbf{x}^{(2)}, \dots, \mathbf{x}^{(n)}) \sim \mathbb{P}_x$  learn a model of  $\mathbb{P}_x$  (for example, fitting a Gaussian distribution via Maximum Likelihood Estimation).



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# WHY GENERATIVE MODELS?

Generative models are capable of uncovering underlying latent variables in a dataset and can be used for

- sampling / data generation
- outlier detection
- missing feature extraction
- image denoising / reconstruction
- representation learning
- planning in reinforcement learning
- ...

# APPLICATION EXAMPLE: IMAGE GENERATION



Source: Karras et al. (2018)

**Figure:** Synthetic faces generated by a Generative Adversarial Network (more on this later).

# APPLICATION EXAMPLE: NEURAL STYLE TRANSFER

A photograph is “redrawn” in the style of another image! (Gatys et al., 2015)



**Figure:** Examples generated on <https://deepart.io/>. The image on the left has been generated by translating the original image (middle) to the style of the image on the right.

# APPLICATION EXAMPLE: NEURAL STYLE TRANSFER

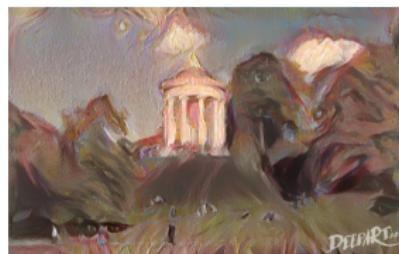
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**Figure:** Examples generated on <https://deeprtf.io/>. The image on the left has been generated by translating the original image (middle) to the style of the image on the right.

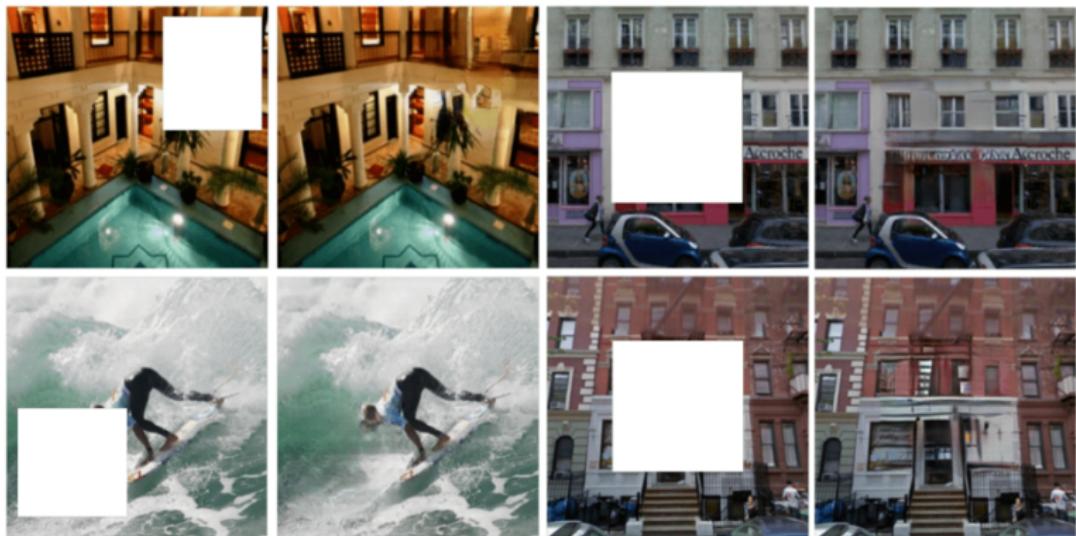
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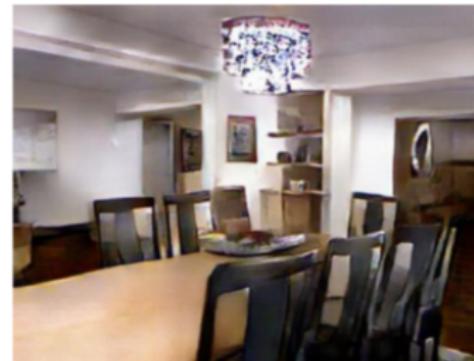
# APPLICATION EXAMPLE: IMAGE INPAINTING



Source: Demir et al (2018)

**Figure:** A generative model fills in the missing portion of the image based on the surrounding context.

# APPLICATION EXAMPLE: SEMANTIC LABELS → IMAGES



Source: Wang et al (2017)

# APPLICATION EXAMPLE: GENERATING IMAGES FROM TEXT

This small blue bird has a short pointy beak and brown on its wings



This bird is completely red with black wings and pointy beak



A small sized bird that has a cream belly and a short pointed bill



A small bird with a black head and wings and features grey wings



Source: Zhang et al (2017)

# REFERENCES

-  Ugur Demir, Gozde Unal (2018)  
Patch-Based Image Inpainting with Generative Adversarial Networks  
<https://arxiv.org/abs/1803.07422>
-  Tero Karras, Timo Aila, Samuli Laine, Jaakko Lehtinen (2018)  
Progressive Growing of GANs for Improved Quality, Stability, and Variation  
<https://arxiv.org/abs/1710.10196>
-  Leon A. Gatys et al. (2015)  
Neural Algorithm of Artistic Style  
<https://arxiv.org/abs/1508.06576>