GENERATIVE MODELLING

Param Hanji • Nov 2022

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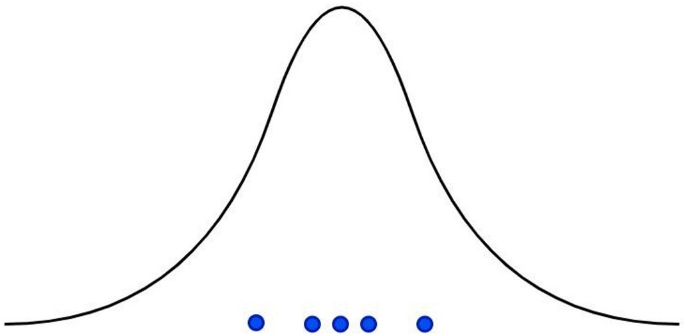
Images as samples

Sample generation



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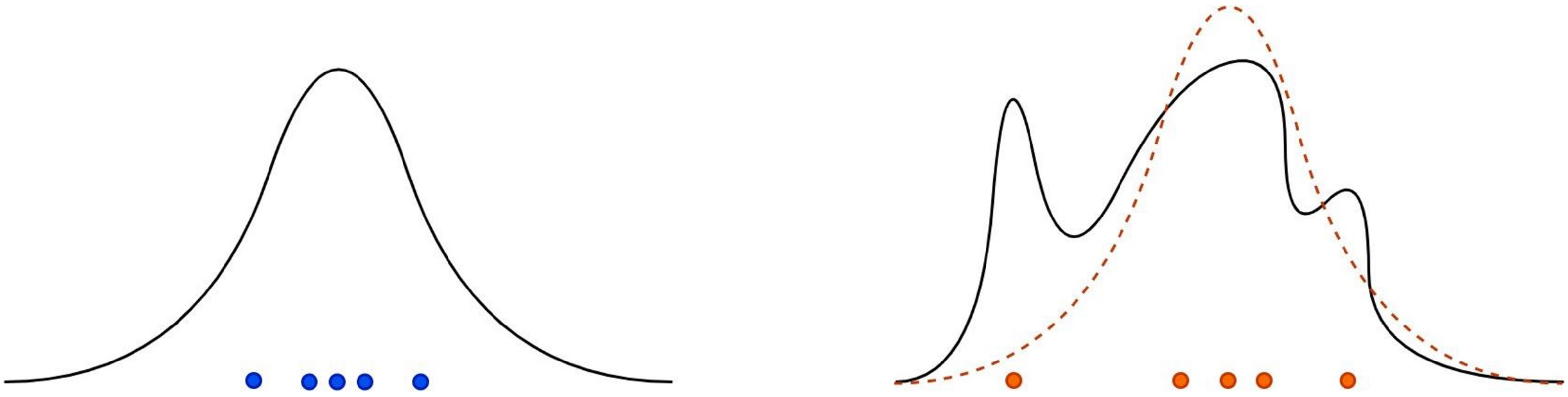
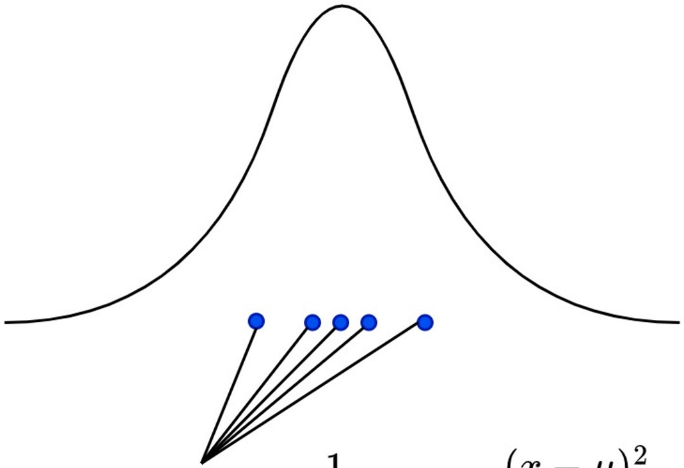
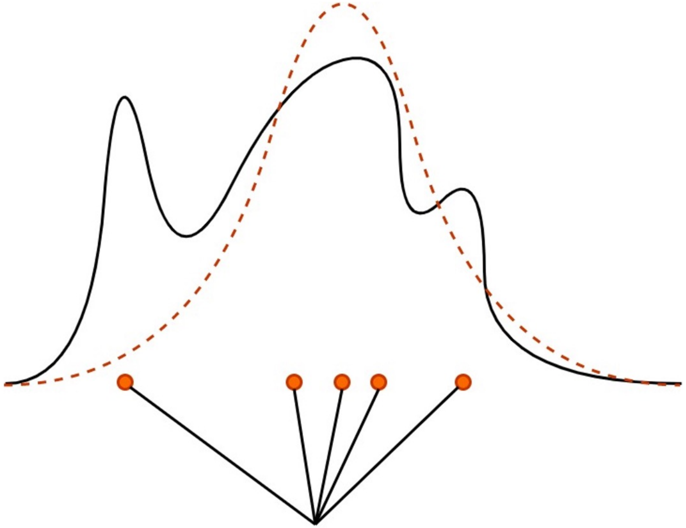
Sample generation



Density estimation



$$p(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp - \frac{(x-\mu)^2}{2\sigma^2}$$

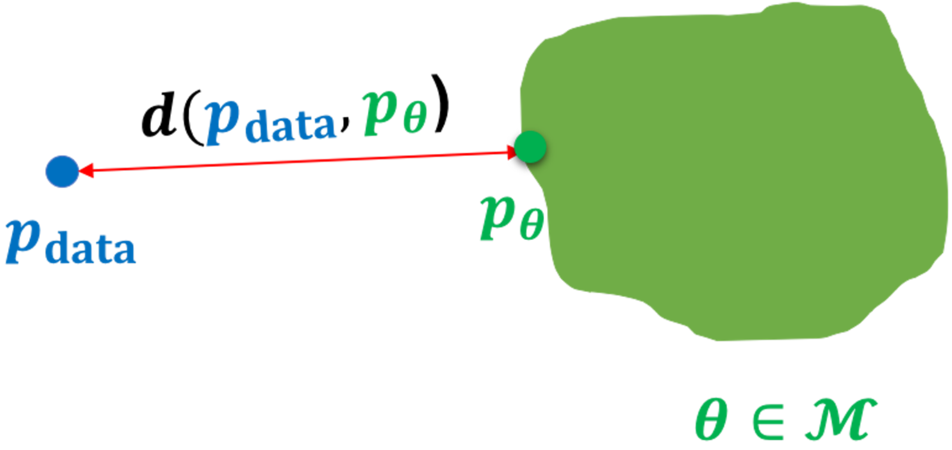


$$p(x) = ?$$

$$q_\theta(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp - \frac{(x-\mu)^2}{2\sigma^2}$$

Training

$$\mathbf{x}^{(j)} \sim p_{\text{data}}$$
$$j = 1, 2, \dots, |\mathcal{D}|$$

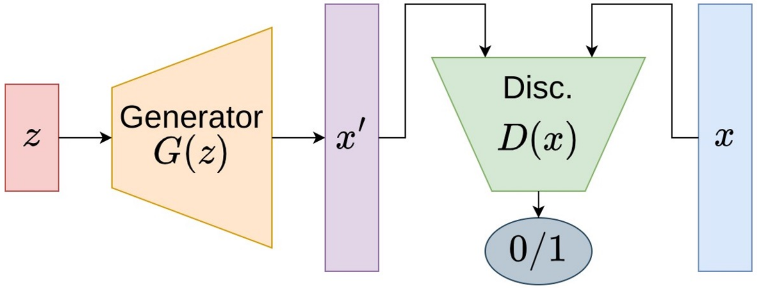


Model family

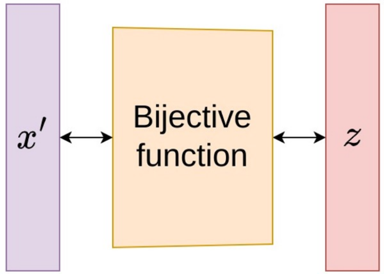
Domains

- Computer vision
- Computer graphics
- Text generation
- Medical imaging
- Audio synthesis
- Astrophysics

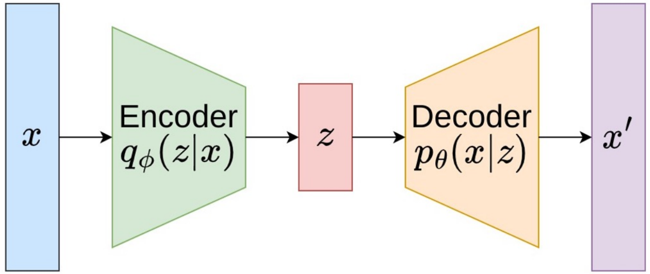
Deep generative modelling



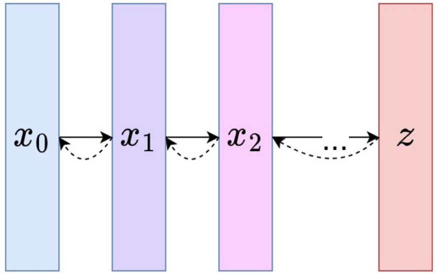
Generative adversarial network



Normalizing flow

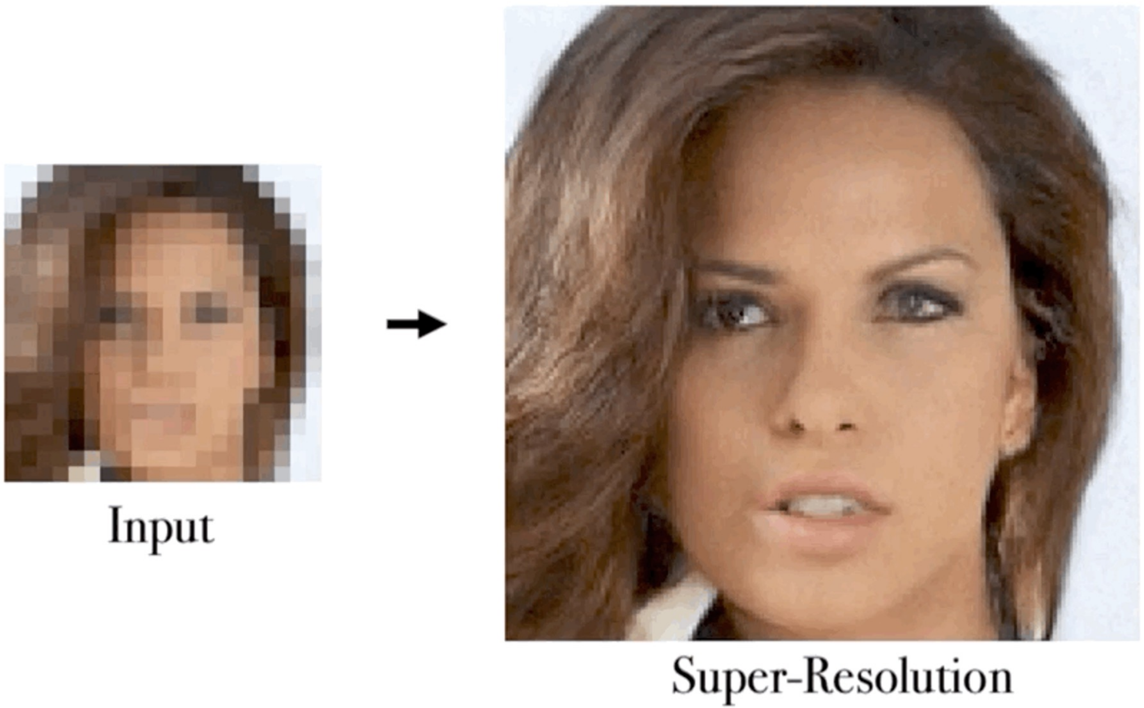


Variational autoencoder



Diffusion method

Inverse problems

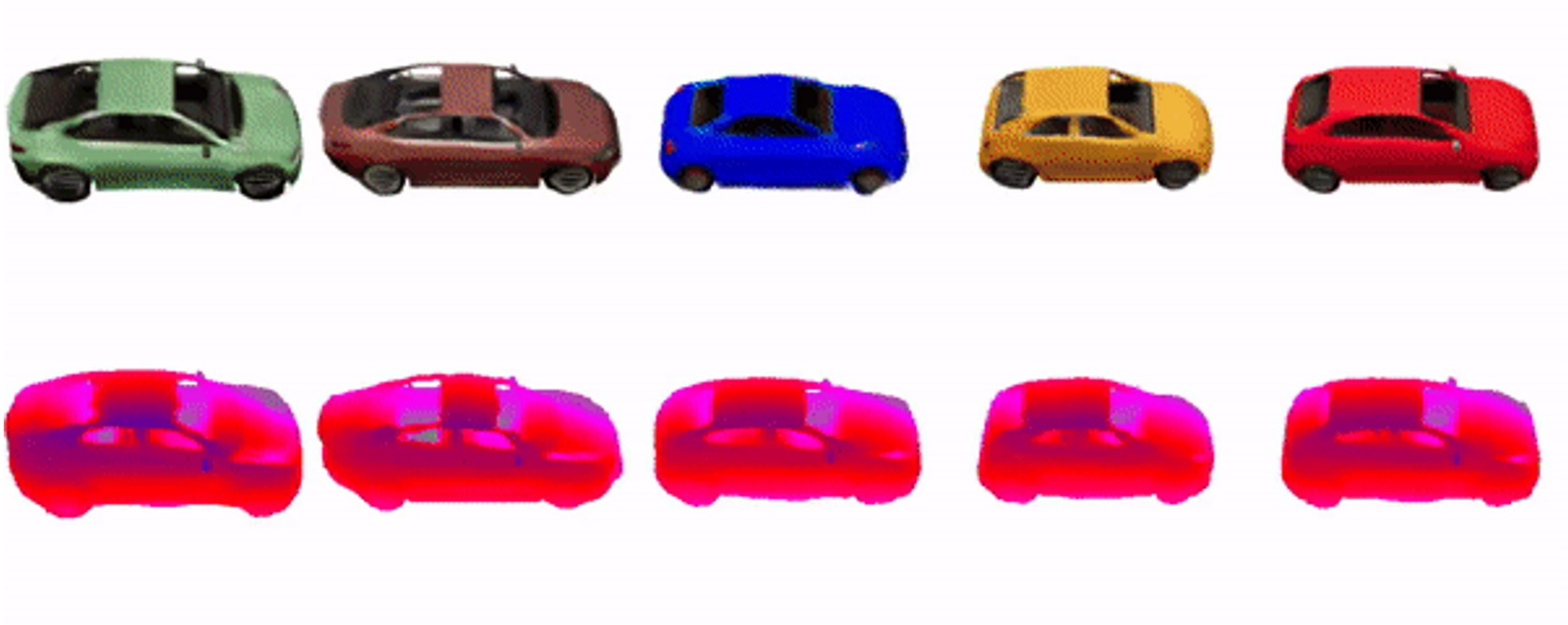


Lugmayr, Andreas, et al. "Srflow: Learning the super-resolution space with normalizing flow." *European conference on computer vision*. Springer, Cham, 2020.

Inverse imaging

- Colorization
- Inpainting
- Uncropping
- Debluring
- Single-image HDR

Inverse graphics



Schwarz, Katja, et al. "Graf: Generative radiance fields for 3d-aware image synthesis." *Advances in Neural Information Processing Systems* 33 (2020): 20154-20166.

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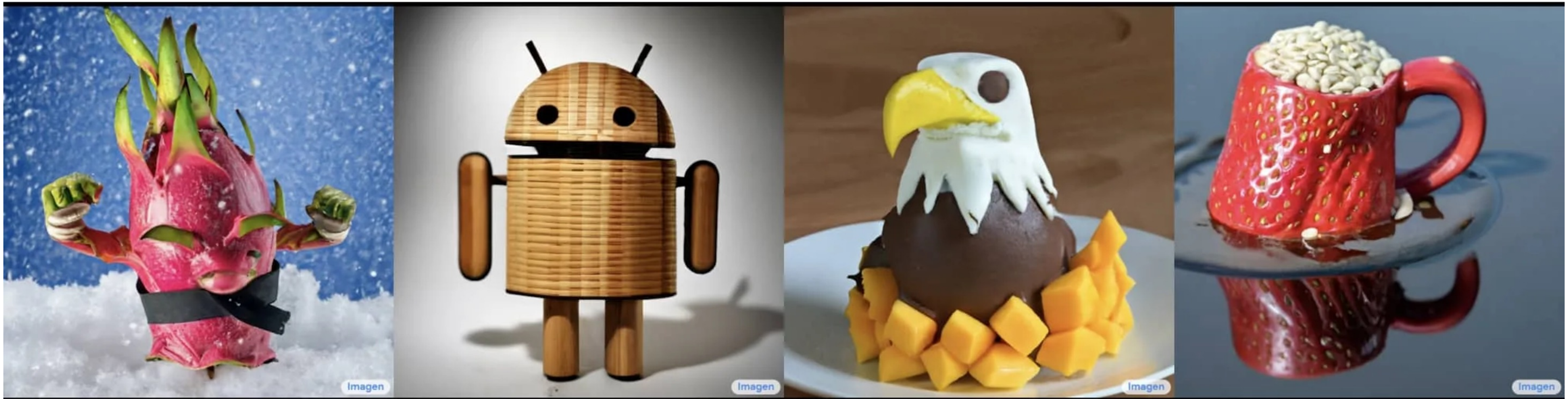
Conditional generation



A dragon fruit wearing karate belt in the snow.

Android Mascot made from bamboo.

A bald eagle made of chocolate powder, mango, and whipped cream.

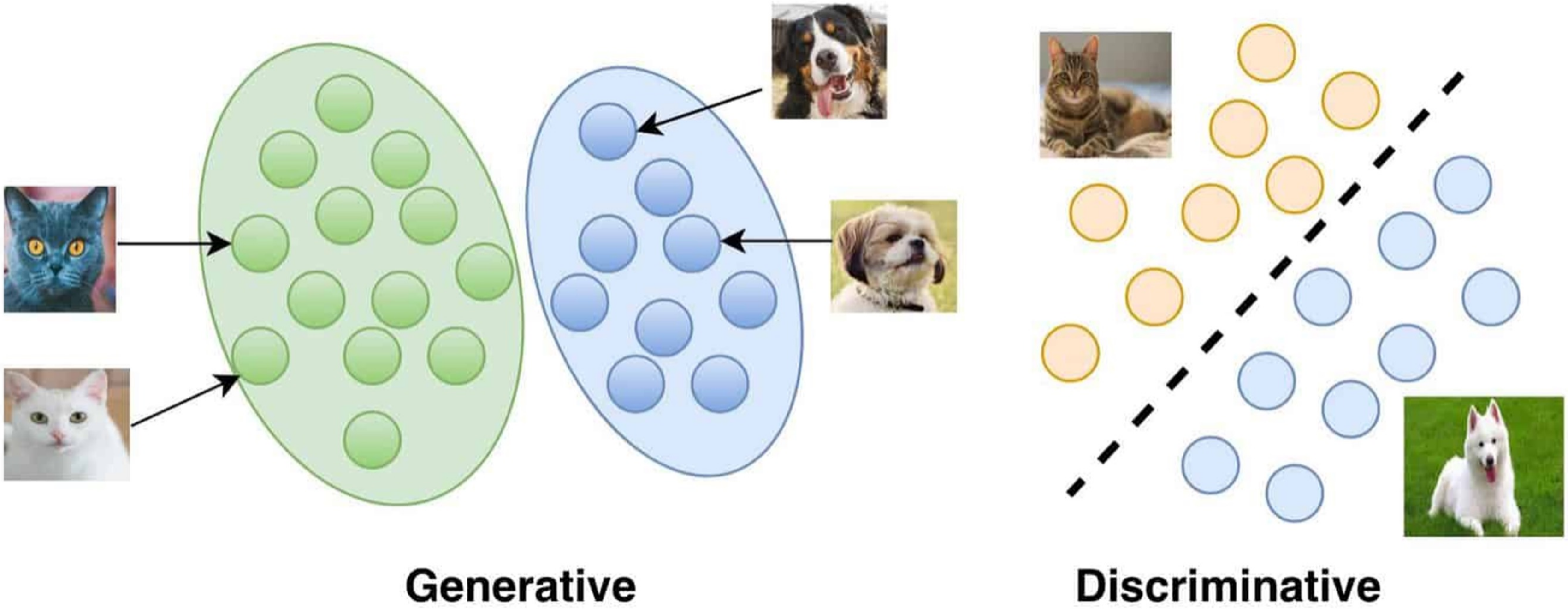
A strawberry mug filled with white sesame seeds. The mug is floating in a dark chocolate sea.

Saharia, Chitwan, et al. "Photorealistic Text-to-Image Diffusion Models with Deep Language Understanding." *arXiv preprint arXiv:2205.11487* (2022).

Image-to-image translation

Zhu, Jun-Yan, et al. "Unpaired image-to-image translation using cycle-consistent adversarial networks." *Proceedings of the IEEE international conference on computer vision*. 2017.

Classification



Mackowiak, Radek, et al. "Generative classifiers as a basis for trustworthy image classification." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2021.

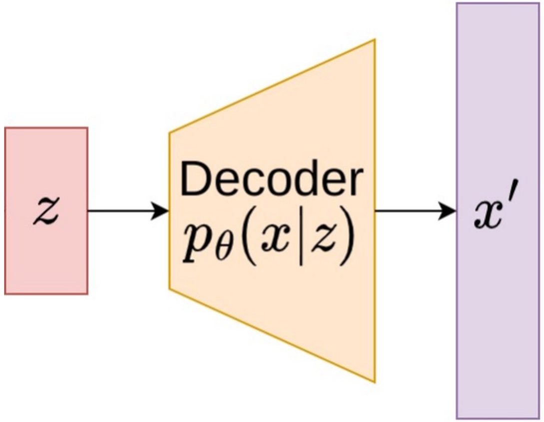
Requirements

- Handle high dimensional data
- Fast, efficient sampling
- High sample quality
- Diverse samples
- [Optional] Density evaluation
- Low dimensional latent

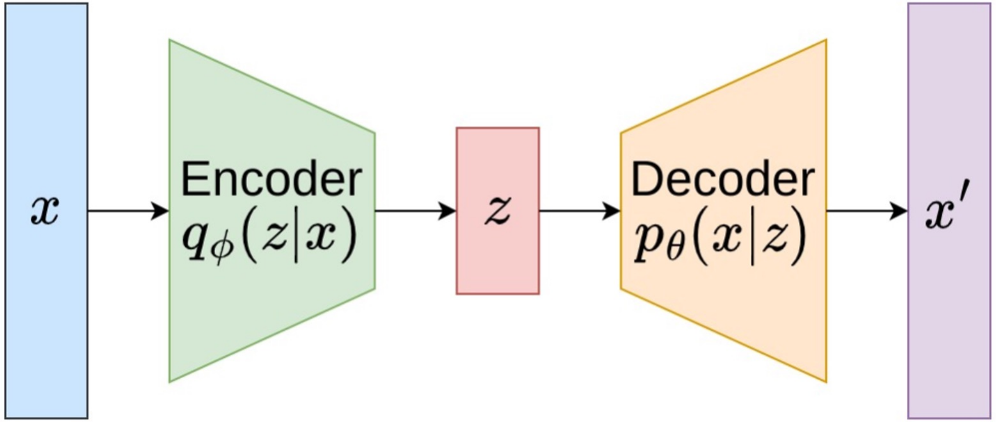
Variational autoencoder

$$\theta^* = \arg\max_\theta \sum_{i=1}^{n} \log p_\theta(\mathbf{x}^{(i)})$$

$$p_\theta(\mathbf{x}^{(i)}) = \int p_\theta(\mathbf{x}^{(i)}|\mathbf{z})p_\theta(\mathbf{z})d\mathbf{z}$$



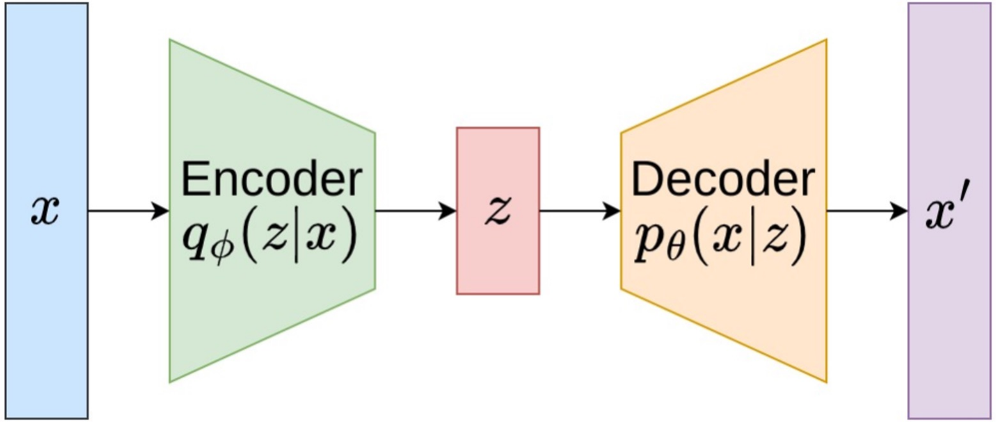
Variational autoencoder



$$D_{\mathrm{KL}}(P \parallel Q) = \int_{-\infty}^{\infty} p(x) \log\left(\frac{p(x)}{q(x)}\right) dx$$

Kingma, Diederik P., and Max Welling. "Auto-encoding variational bayes." *arXiv preprint arXiv:1312.6114* (2013).

Variational autoencoder



$$-L_{\text{VAE}} = \log p_\theta(\mathbf{x}) - D_{\text{KL}}(q_\phi(\mathbf{z}|\mathbf{x}) \| p_\theta(\mathbf{z}|\mathbf{x})) \leq \log p_\theta(\mathbf{x})$$

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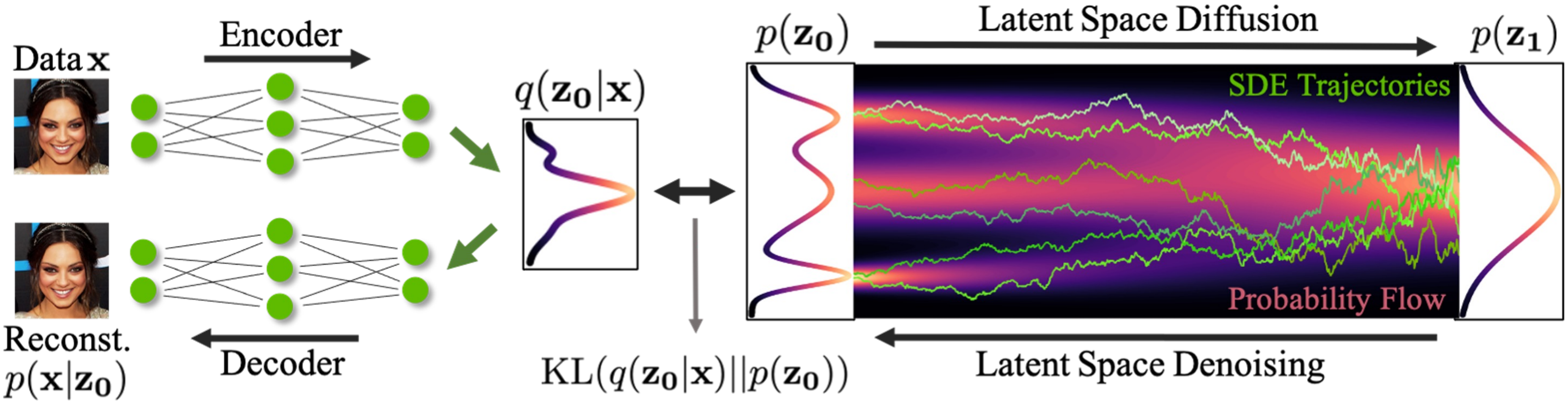
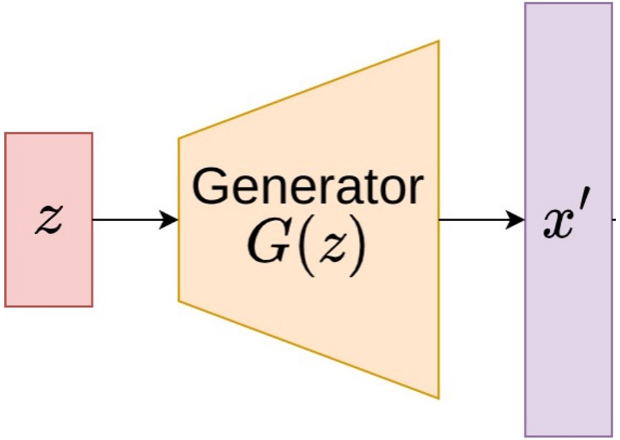
Kingma, Diederik P., and Max Welling. "Auto-encoding variational bayes." *arXiv preprint arXiv:1312.6114* (2013).

Variational autoencoder

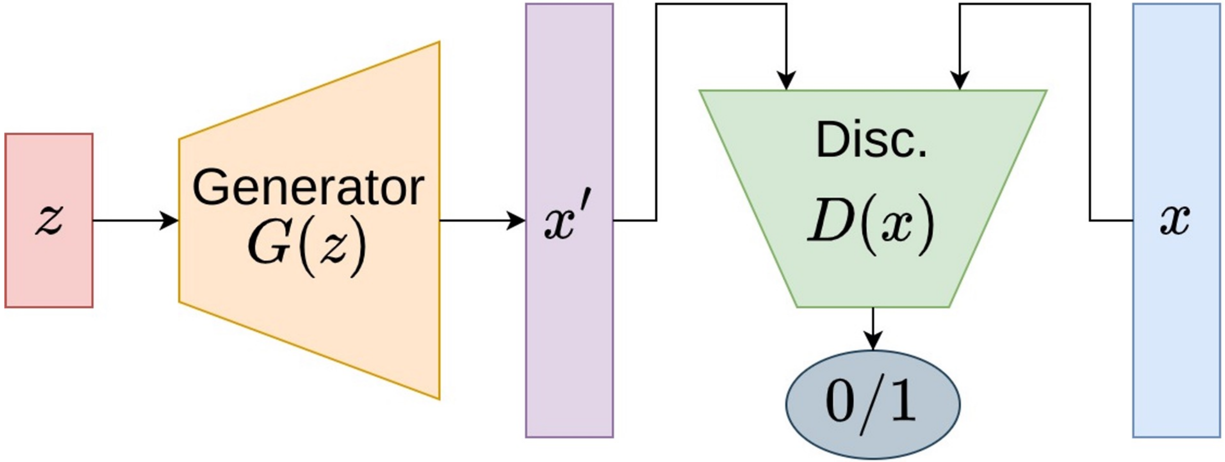


Vahdat, Arash, Karsten Kreis, and Jan Kautz. "Score-based generative modeling in latent space." *Advances in Neural Information Processing Systems* 34 (2021): 11287-11302.

Generative adversarial network



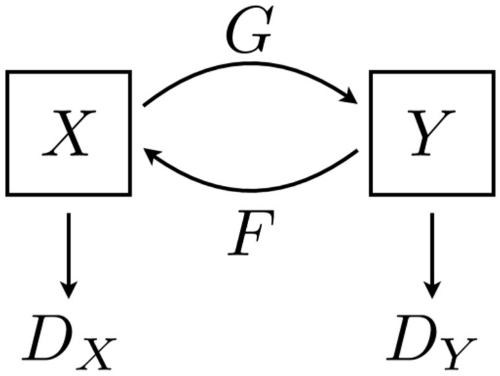
Generative adversarial network



$$\min_G \max_D V(D,G) = \mathbb{E}_{\boldsymbol{x}\sim p_{\text{data}}(\boldsymbol{x})}[\log D(\boldsymbol{x})] + \mathbb{E}_{\boldsymbol{z}\sim p_{\boldsymbol{z}}(\boldsymbol{z})}[\log(1 - D(G(\boldsymbol{z})))]$$

Goodfellow, Ian, et al. "Generative adversarial networks." *Advances in Neural Information Processing Systems (2014)*..

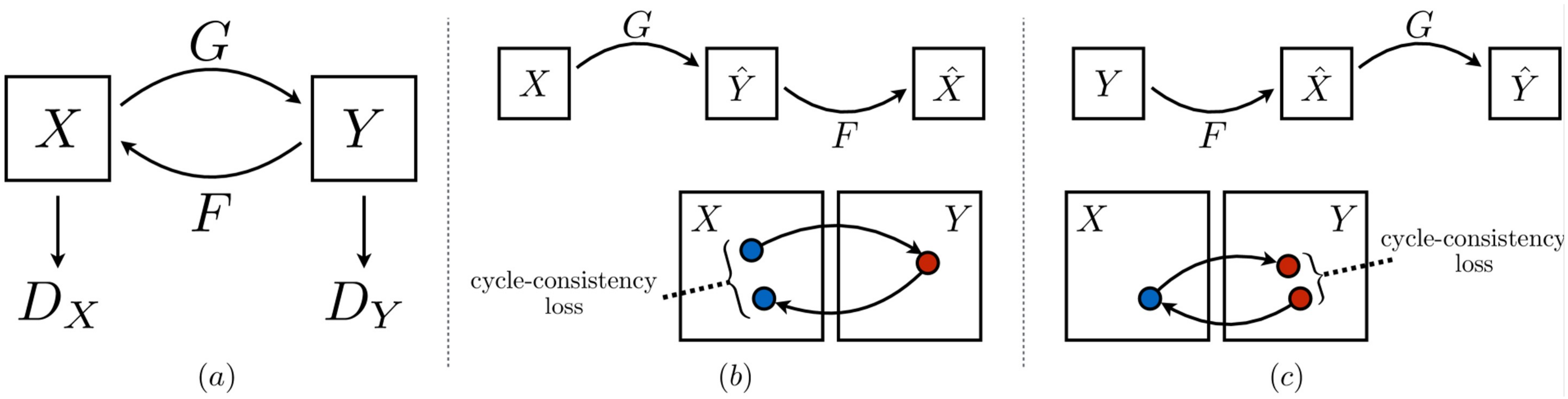
Cycle-GAN



(a)

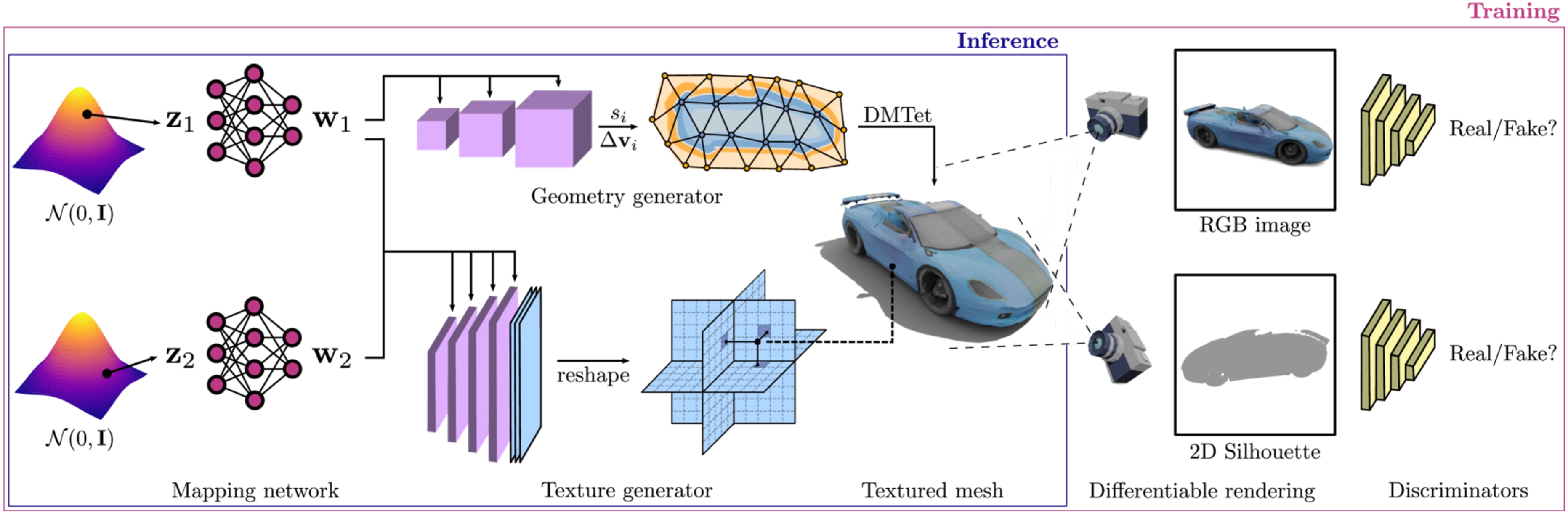
Zhu, Jun-Yan, et al. "Unpaired image-to-image translation using cycle-consistent adversarial networks." *Proceedings of the IEEE international conference on computer vision*. 2017.

Cycle-GAN



Zhu, Jun-Yan, et al. "Unpaired image-to-image translation using cycle-consistent adversarial networks." *Proceedings of the IEEE international conference on computer vision*. 2017.

GAN - complex models



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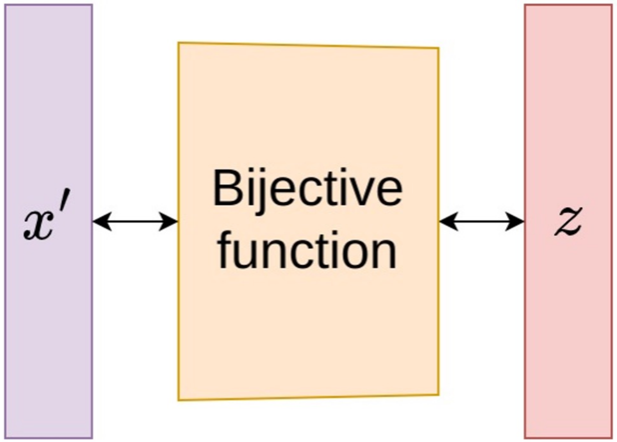
Zhu, Jun-Yan, et al. "Unpaired image-to-image translation using cycle-consistent adversarial networks." *Proceedings of the IEEE international conference on computer vision*. 2017.

Normalizing flows



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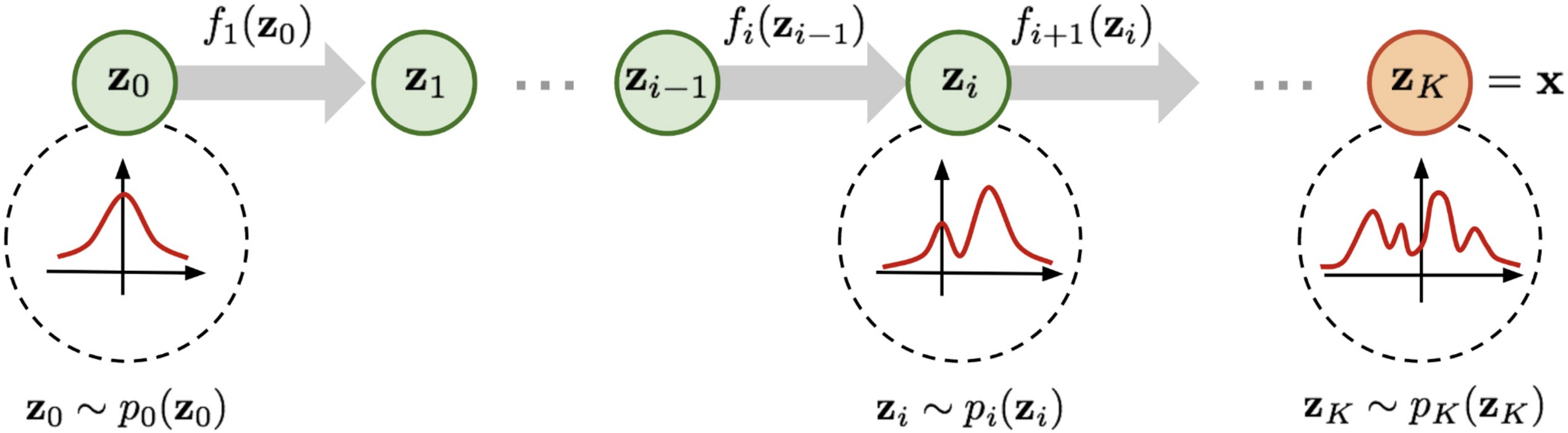
Goodfellow, Ian, et al. "Generative adversarial networks." *Advances in Neural Information Processing Systems (2014)..*

Normalizing flows



$$p_i(\mathbf{z}_i) = p_{i-1}(f_i^{-1}(\mathbf{z}_i)) \left| \det \frac{d f_i^{-1}}{d \mathbf{z}_i} \right|$$

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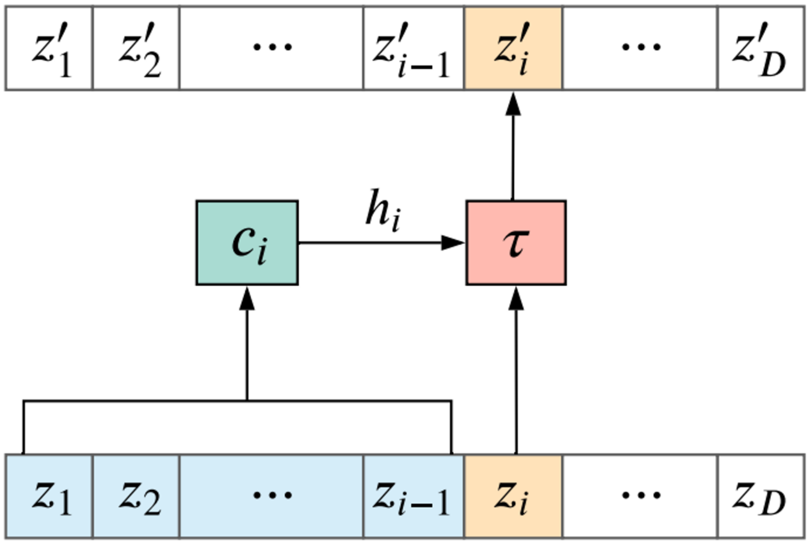
Rezende, Danilo, and Shakir Mohamed. "Variational inference with normalizing flows." *International conference on machine learning*. PMLR, 2015.

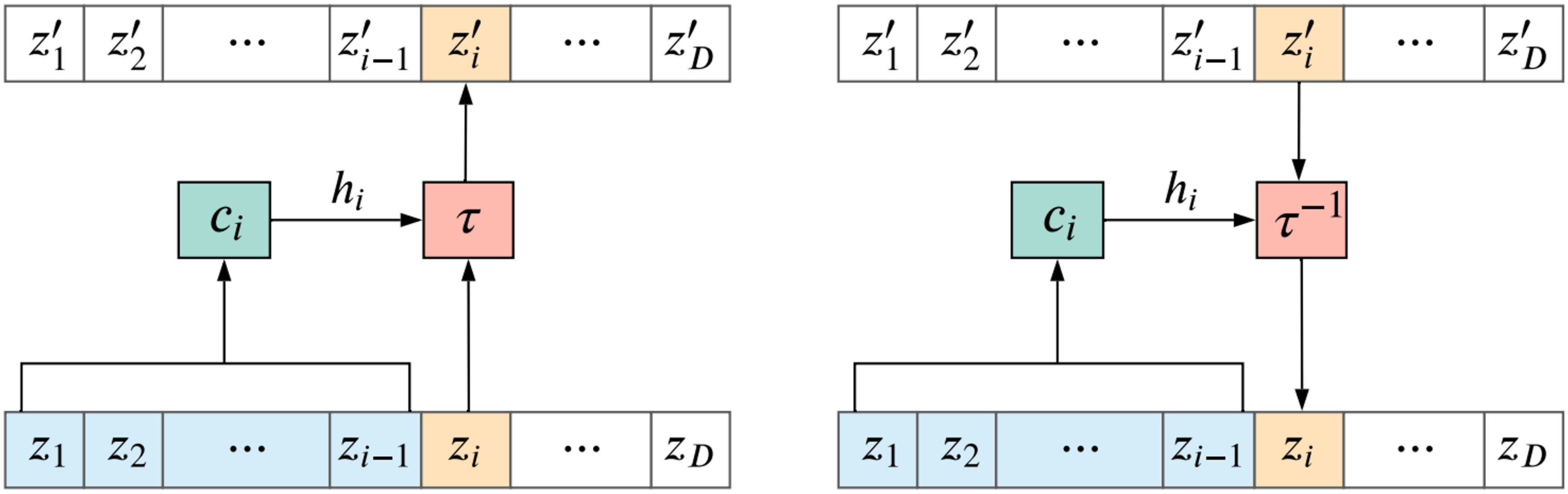
Normalizing flows - coupling



(a) Forward

Dinh, Laurent, Jascha Sohl-Dickstein, and Samy Bengio. "Density estimation using real nvp." *arXiv preprint arXiv:1605.08803* (2016).

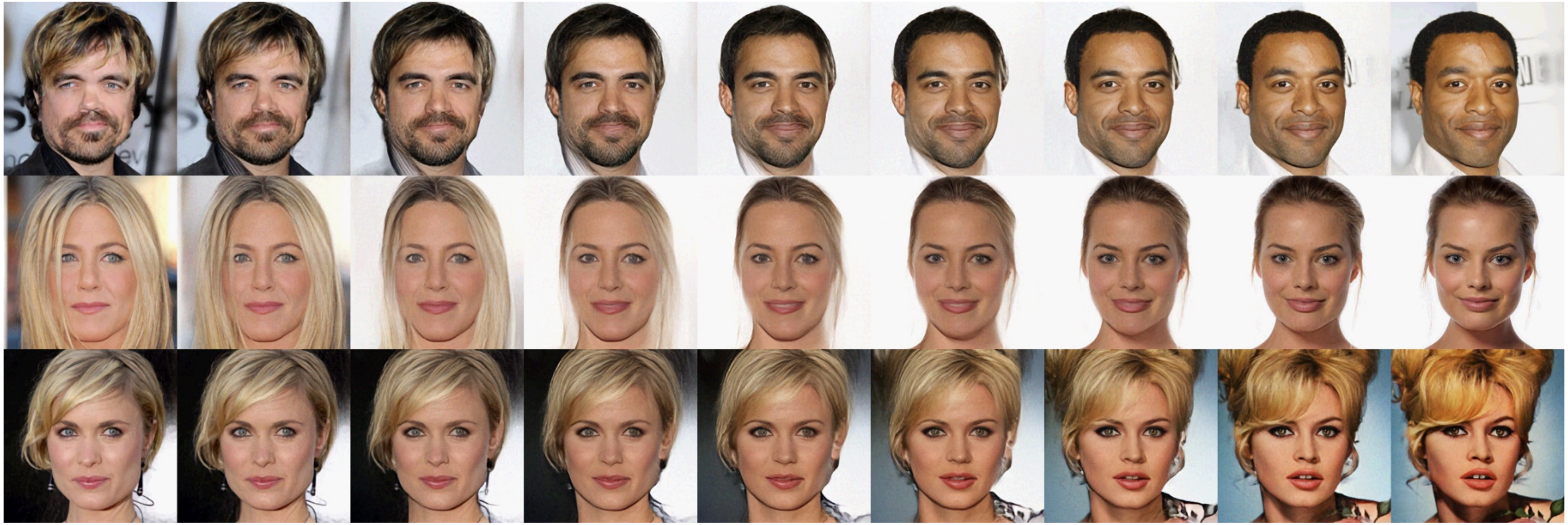
Normalizing flows - coupling



(a) Forward (b) Inverse

Dinh, Laurent, Jascha Sohl-Dickstein, and Samy Bengio. "Density estimation using real nvp." *arXiv preprint arXiv:1605.08803* (2016).

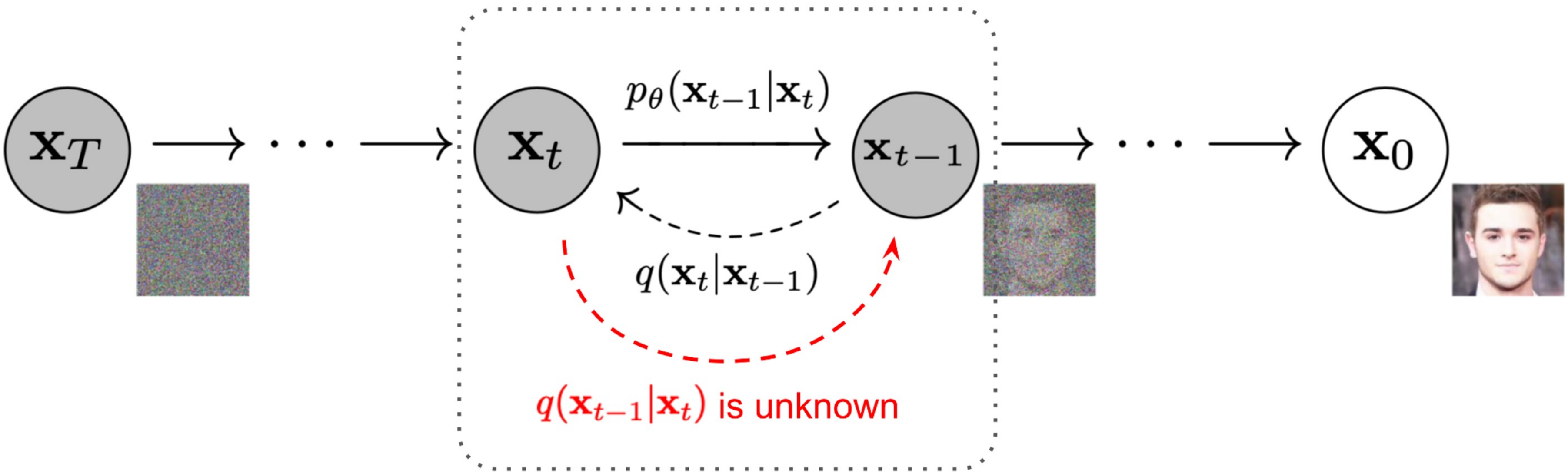
Flows - latent manipulation



Kingma, Durk P., and Prafulla Dhariwal. "Glow: Generative flow with invertible 1x1 convolutions." *Advances in neural information processing systems* 31 (2018).

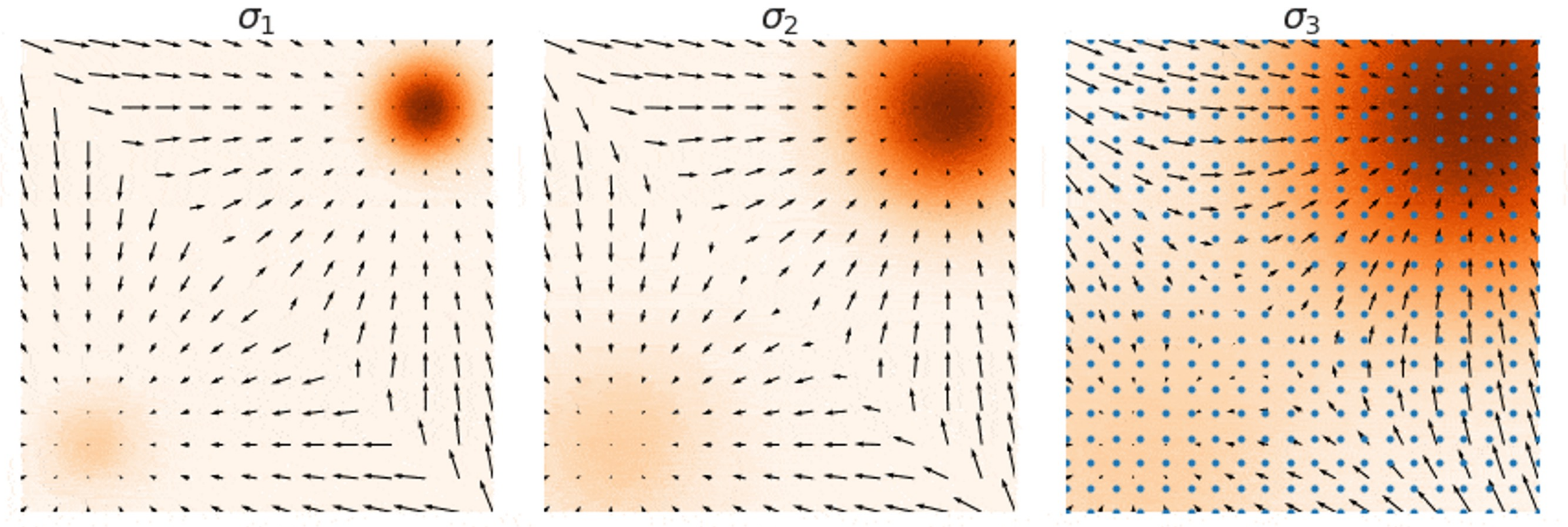
Diffusion models

Use variational lower bound

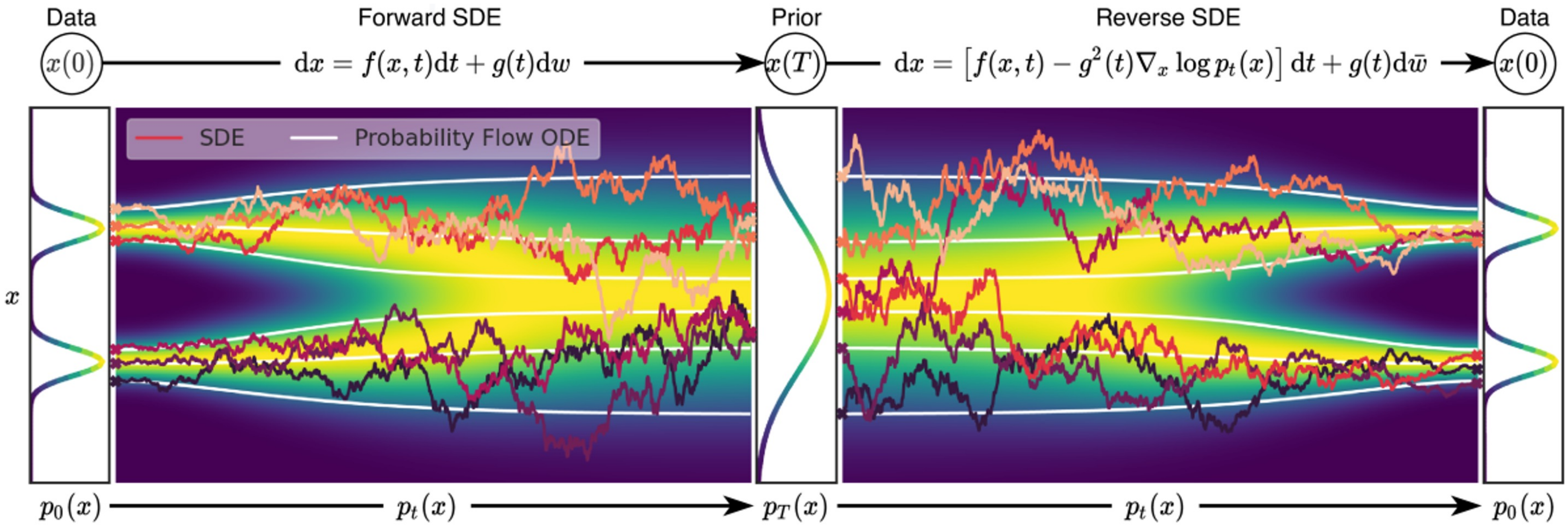


Sohl-Dickstein, Jascha, et al. "Deep unsupervised learning using nonequilibrium thermodynamics." *International Conference on Machine Learning*. PMLR, 2015.

Score matching

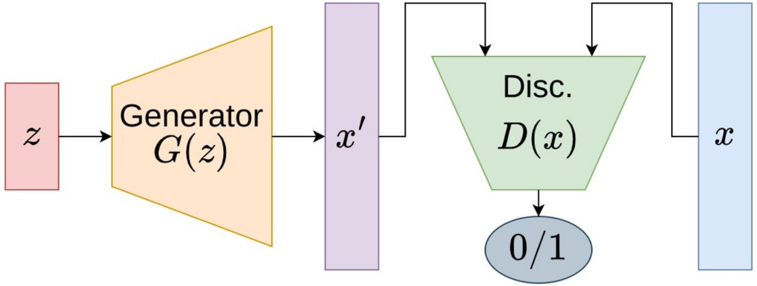


Unified perspective

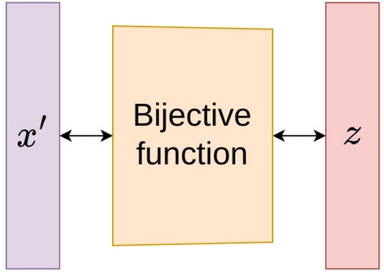


Song, Yang, et al. "Score-based generative modeling through stochastic differential equations." *arXiv preprint arXiv:2011.13456* (2020).

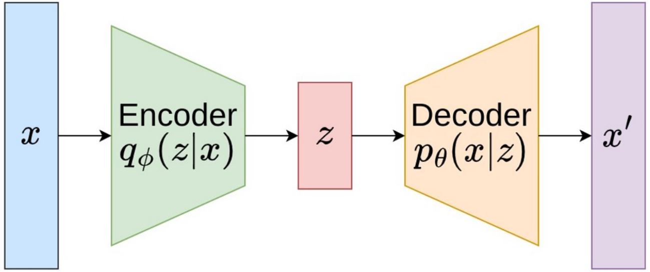
Deep generative modelling



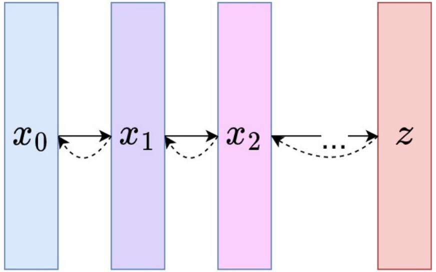
Generative adversarial network



Normalizing flow

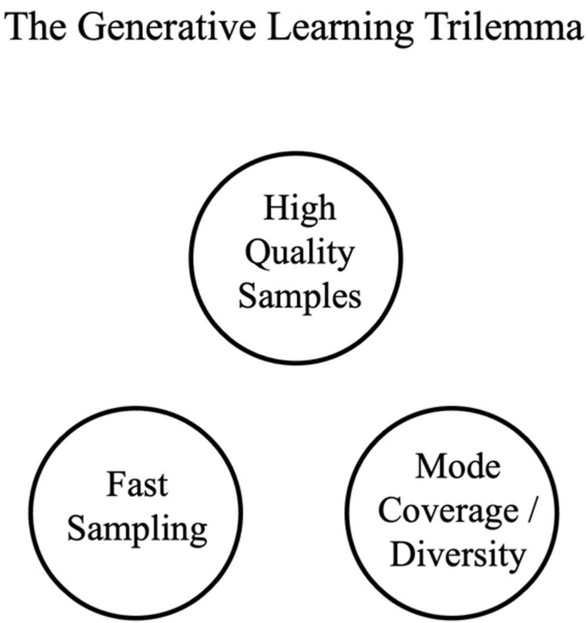


Variational autoencoder



Diffusion method

Summary


The Generative Learning Trilemma
High Quality Samples
Fast Sampling
Mode Coverage / Diversity