Variational Auto-encoders:
Representations for image generation and semi-supervised learning

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BACKGROUND, DATA, TOOLS

- Variational auto-encoders are useful for generating new examples from observed data
- Learns latent encoding of data
- Can be used for semi-supervised learning
- Data: MNIST digits dataset and SVHN dataset
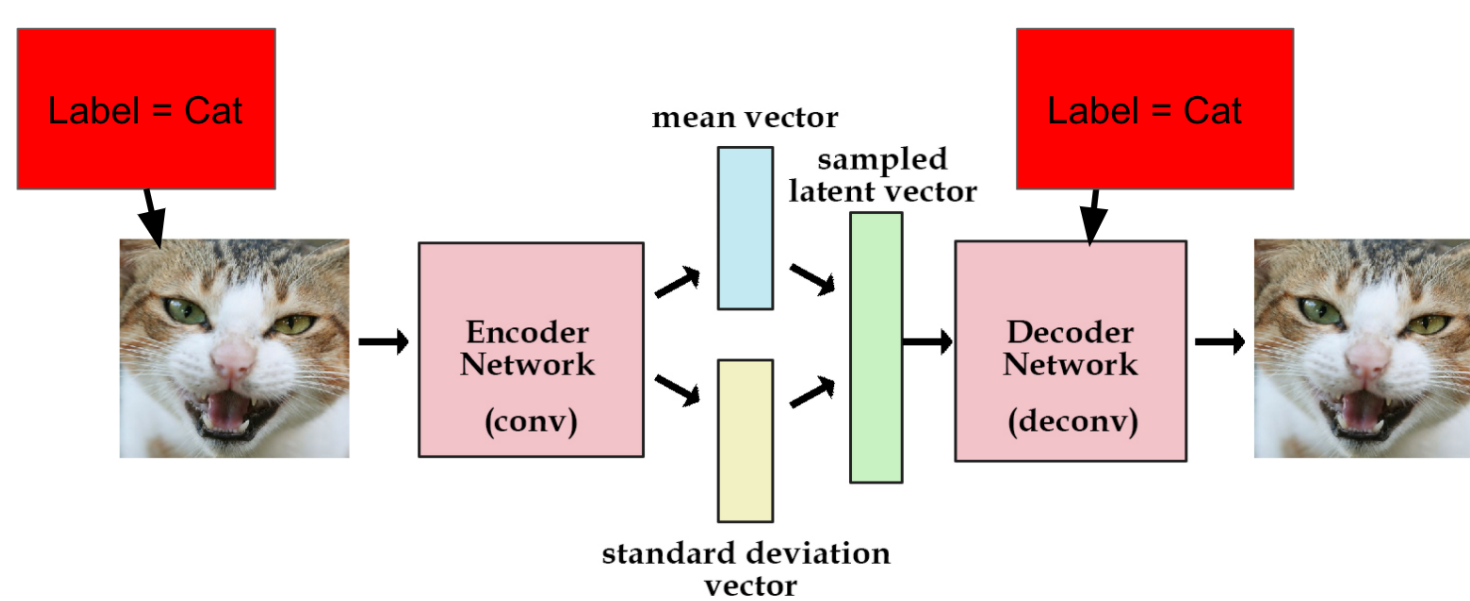- Tools: TensorFlow, GeForce GTX 770 GPU

VARIATIONAL AUTO-ENCODER

- latent variable model: $z \sim \mathcal{N}(0, I)$, $x \mid z \sim f(x; z, \theta)$ (e.g. Bernoulli)
- variational inference: maximize lower bound on log likelihood

$$\log p(x) \geq \mathbb{E}_{z \sim Q(\cdot \mid x)}[\log p(x \mid z)] - \mathrm{KL}(Q(z \mid x) \| p(z)).$$

CONDITIONAL VAE (CVAE)

- condition everything on label y

$$\log p(x \mid y) \geq \mathbb{E}_{z \sim Q(\cdot \mid y, x)}[\log p(x \mid y, z)] - \mathrm{KL}(Q(z \mid x, y) \| p(z \mid y)).$$

CVAE FOR COMPLETION

CVAE FOR STYLE TRANSFER

SEMI-SUPERVISED LEARNING (SSL) VAE

- Handle datasets with missing labels
- Models label distribution
- Labeled and unlabeled examples enter loss differently

$$\log p(x, y) \geq \mathbb{E}_{z \sim Q(z \mid x, y)}[\log p(x \mid y, z) + \log p(y)] - \mathrm{KL}(Q(z \mid x, y) \| p(z)) =: -\mathcal{L}(x, y)$$
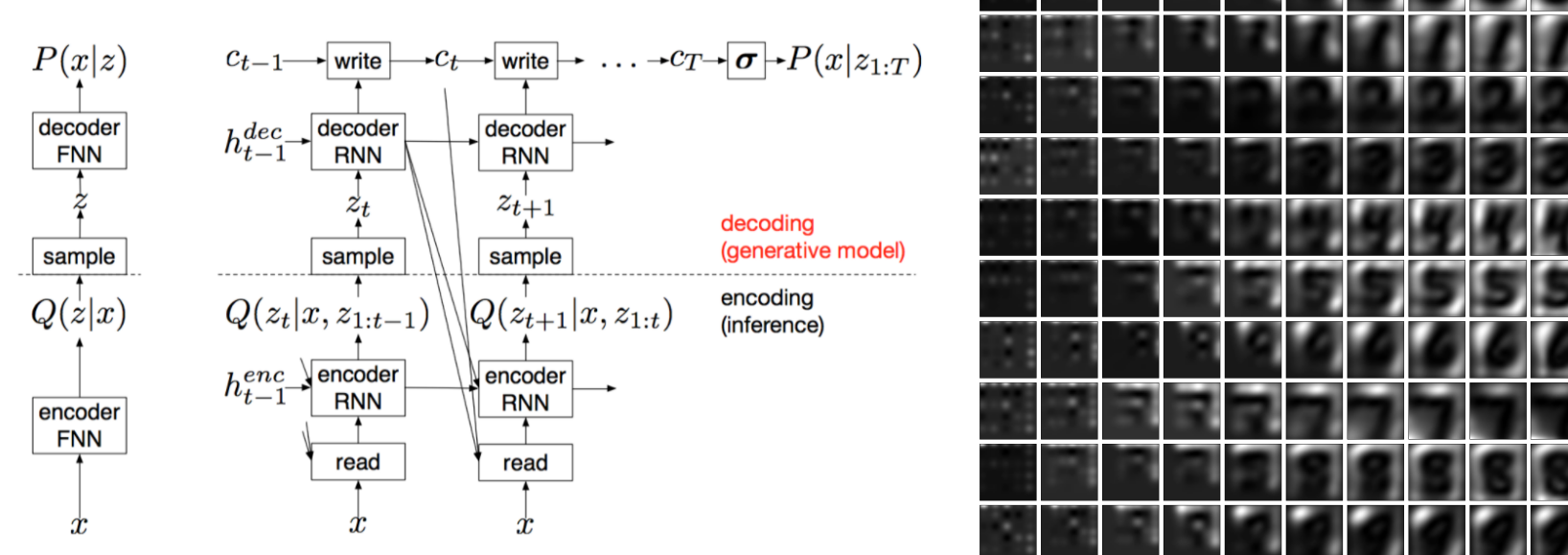
$$\log p(x) \geq \sum_y q(y \mid x)(-\mathcal{L}(x, y)) + H(q(y \mid x))$$

Validation/test error on MNIST
(55000 training examples)

	1000 labeled	600 labeled
Fully connected	4.7%/ 5.1%	11.5%/12.0%
Convolutional	4.2%/4.8%	6.0%/6.2%
Kingma et al. [3]	2.4%	2.6%

DRAW

- attention-based sequential generation
- RNN structure

ADDING GANs

- VAE output is often blurry
- Add discriminator to encourage sharpness
- Replace decoder loss with comparison of discriminator layers
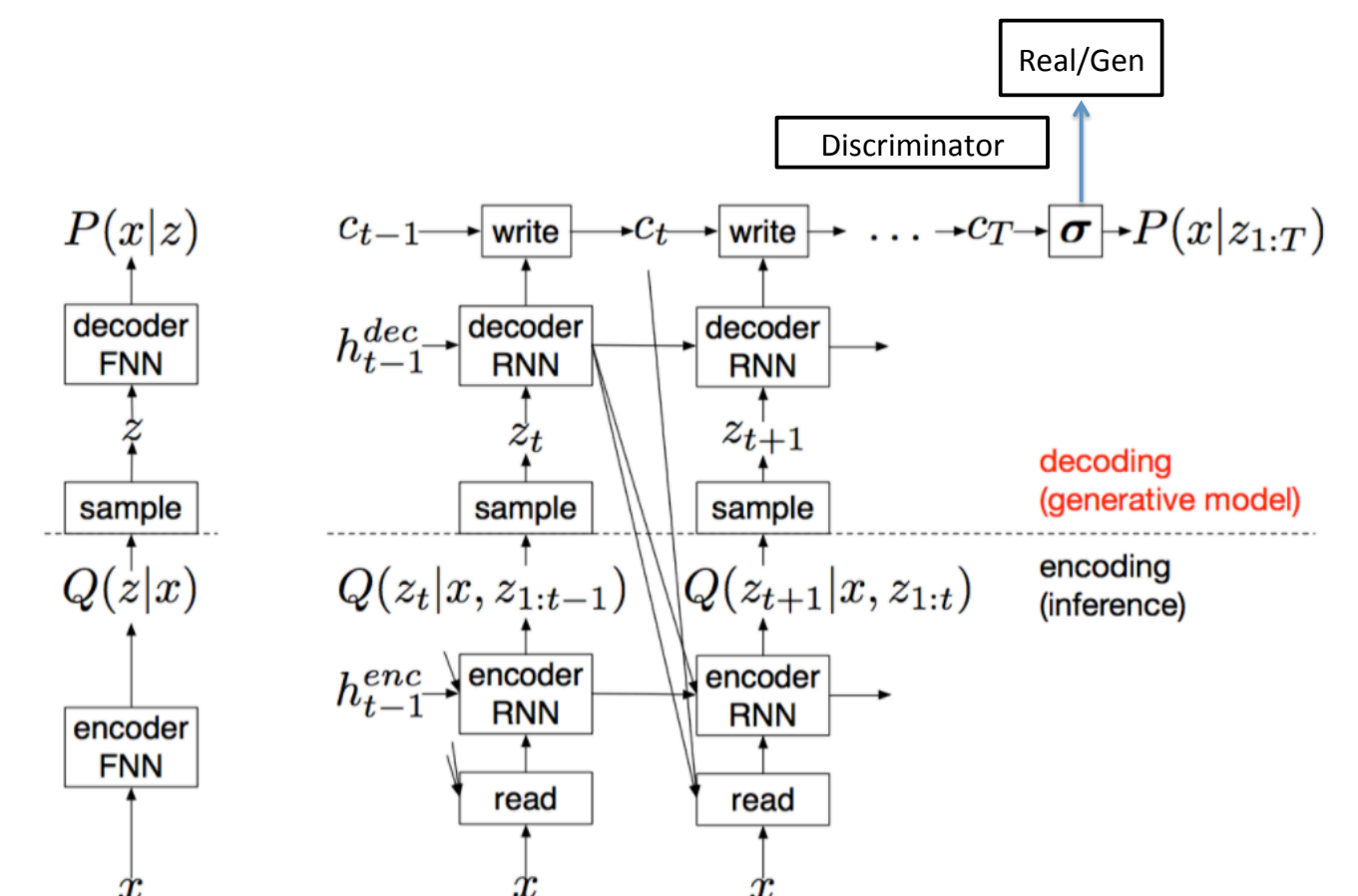

CVAE WITH GAN

CVAEGAN results here

SSL WITH GANs

CVAEGAN results here

DRAW WITH GANs

- Add GAN on the top of the last output of DRAW
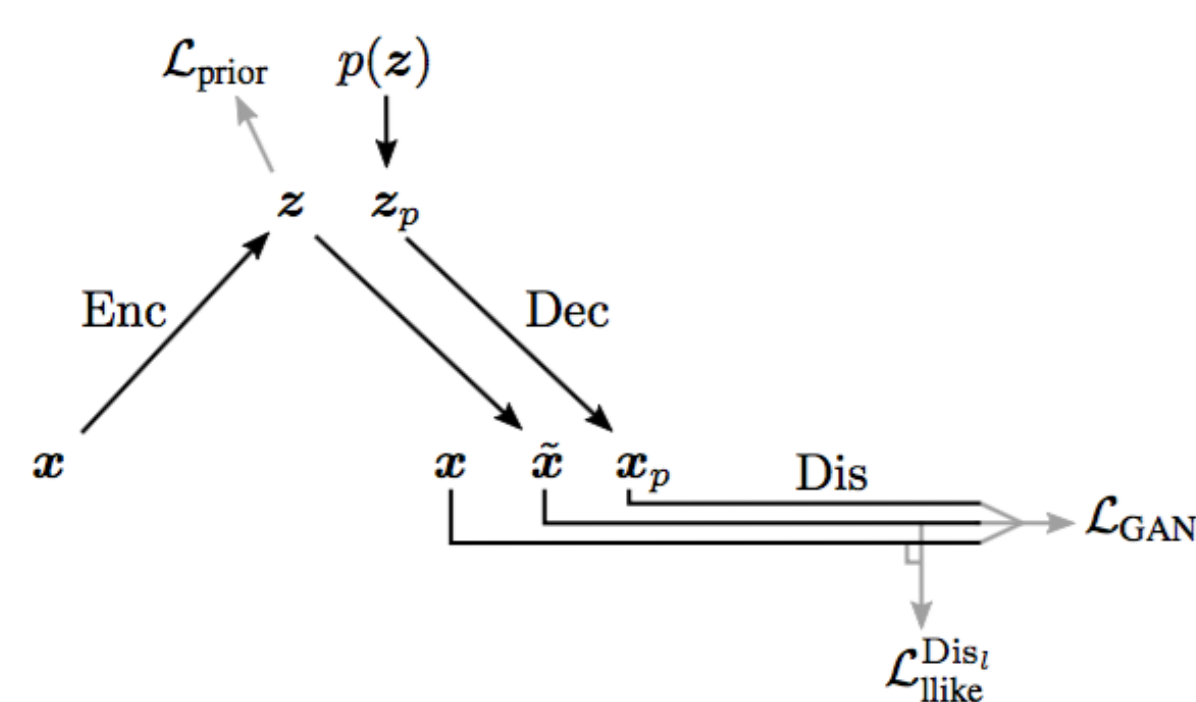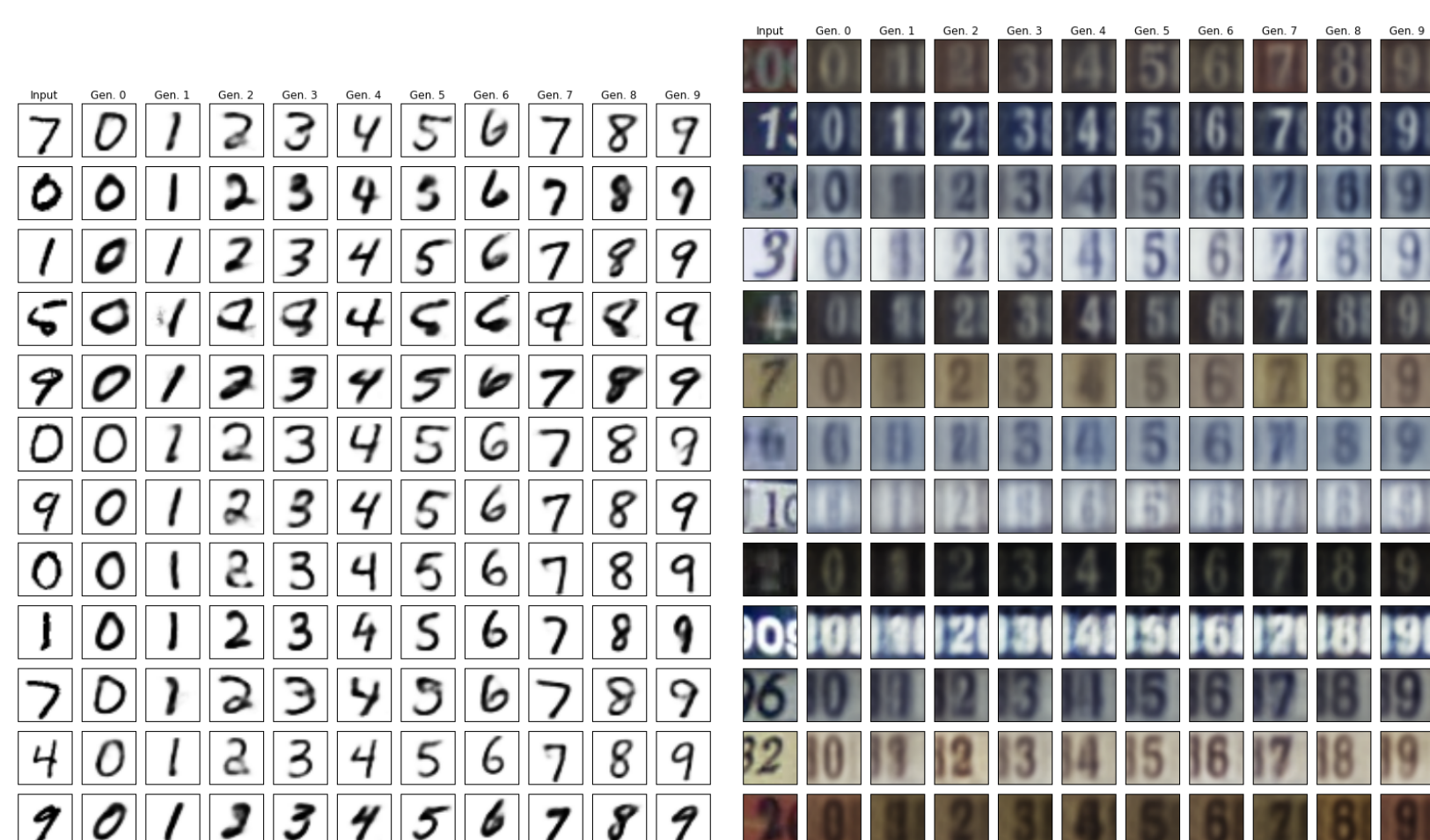

FUTURE DIRECTIONS

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REFERENCES

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[2] Karol Gregor, Ivo Danihelka, Alex Graves, Danilo Jimenez Rezende, and Daan Wierstra. DRAW: A recurrent neural network for image generation. *arXiv preprint arXiv:1502.04623*, 2015.

[3] Diederik P Kingma, Shakir Mohamed, Danilo Jimenez Rezende, and Max Welling. Semi-supervised learning with deep generative models. In *Advances in Neural Information Processing Systems*, pages 3581–3589, 2014.

[4] Diederik P Kingma and Max Welling. Auto-encoding variational bayes. *arXiv preprint arXiv:1312.6114*, 2013.

[5] Anders Boesen Lindbo Larsen, Søren Kaae Sønderby, and Ole Winther. Autoencoding beyond pixels using a learned similarity metric. *arXiv preprint arXiv:1512.09300*, 2015.