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

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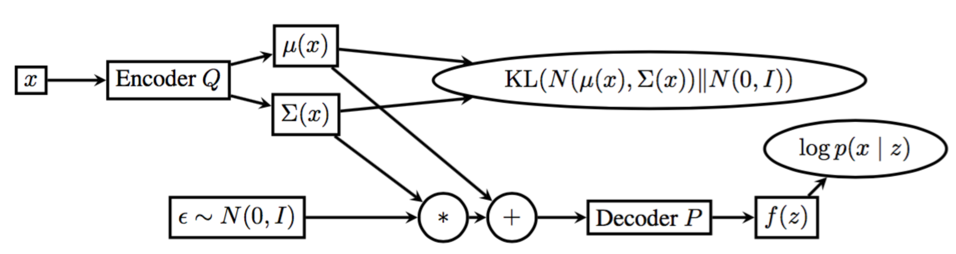
BACKGROUND, DATA, TOOLS

- 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 (VAE)

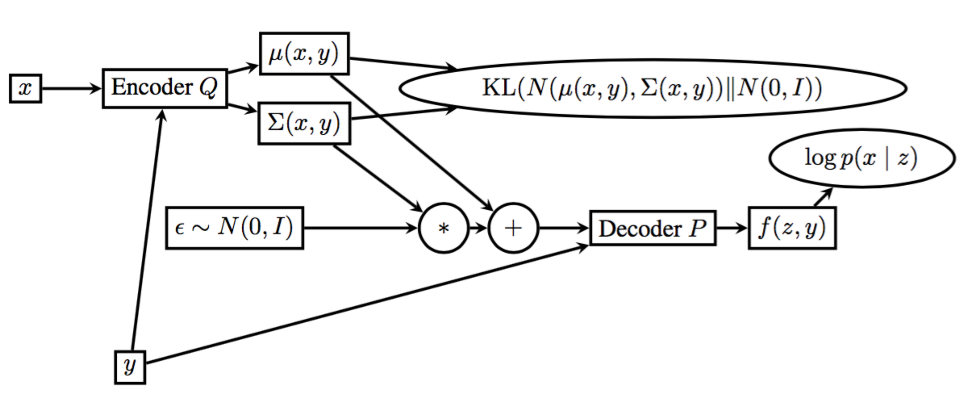
- latent variable model: $z \sim \mathcal{N}(0, I)$, $x \mid z \sim f(x; z, \theta)$ (e.g. Bernoulli)
- variational inference: maximize lower bound on log likelihood



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

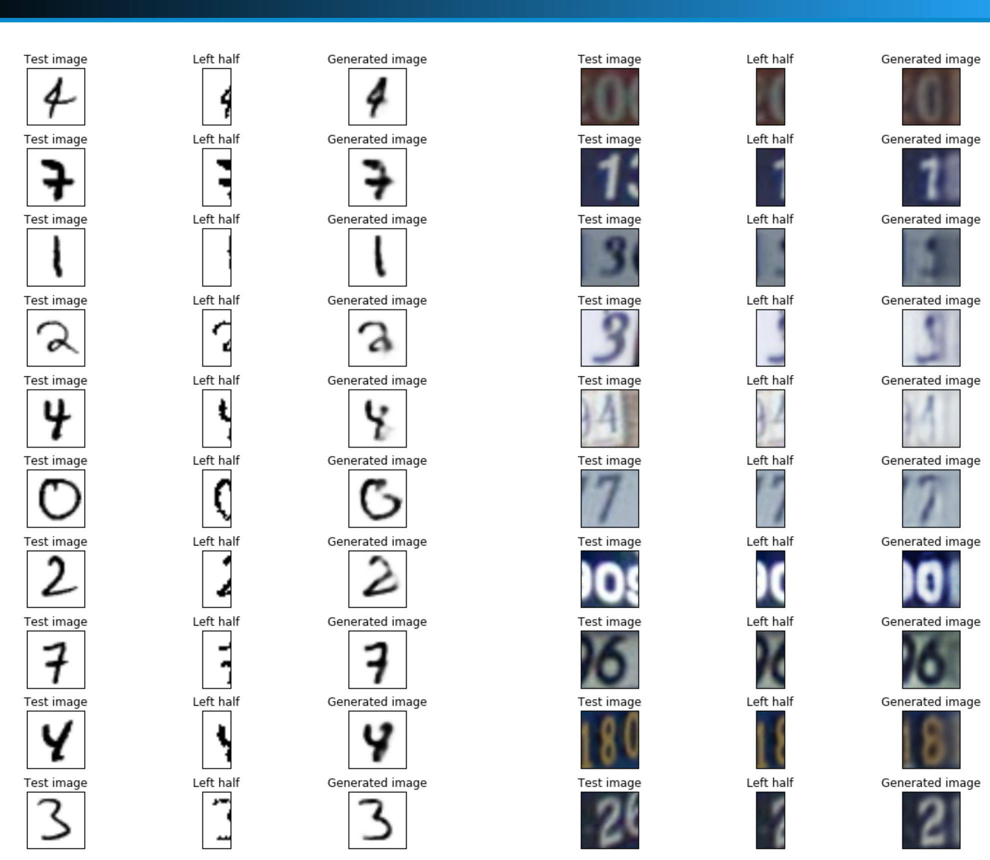
CONDITIONAL VAE (CVAE)

- condition everything on label y

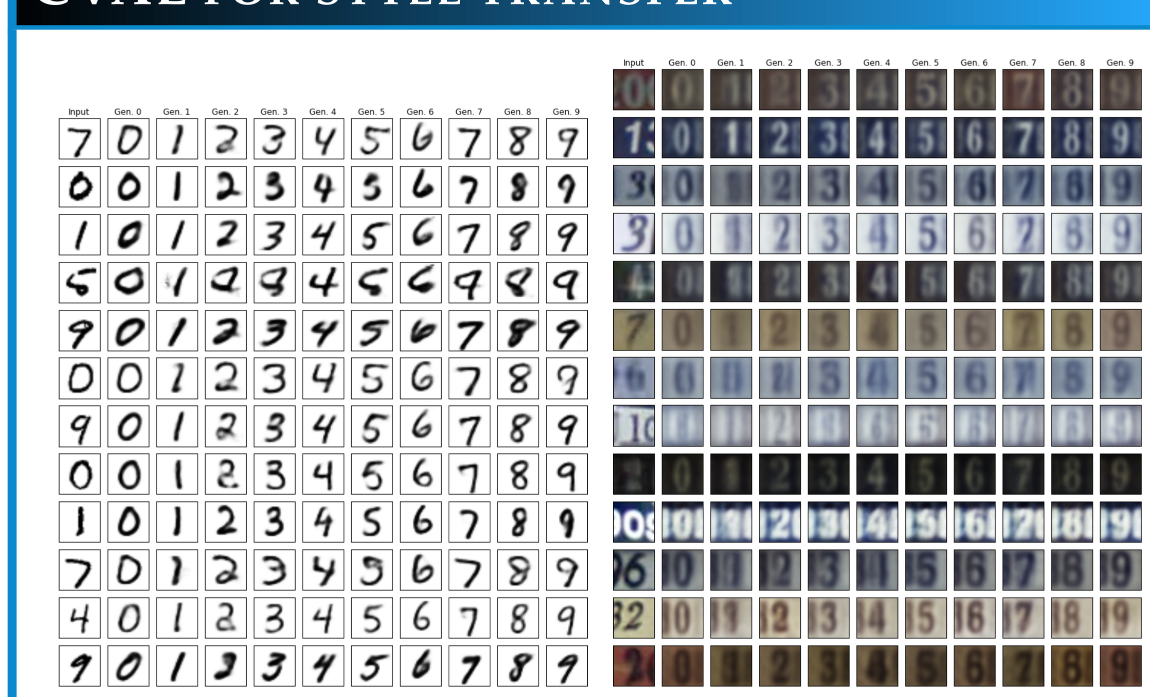


$$\log p(x \mid y) \geq \mathbb{E}_{z \sim Q(\cdot \mid y, x)}[\log p(x \mid y, z)] - \mathrm{KL}(Q(z \mid x, y) \| p(z \mid y)).$$

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

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

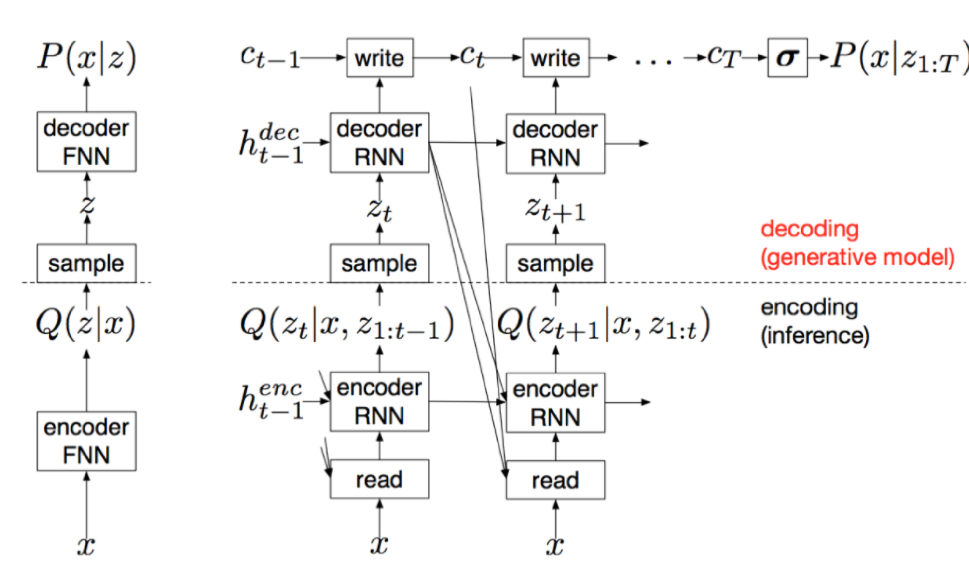
$$\log p(x) \geq \sum_y q(y \mid x)(-\mathcal{L}(x, y)) + H(q(y \mid x))$$

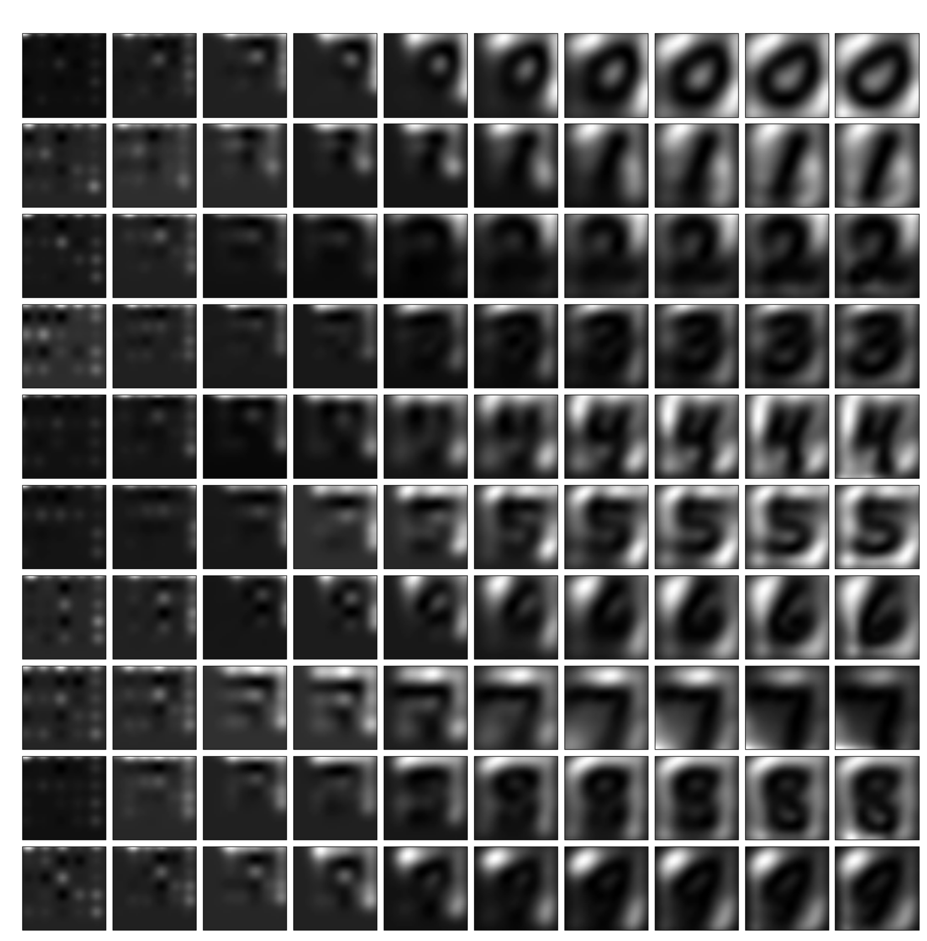
Validation/test error on MNIST (55000 training examples)

	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

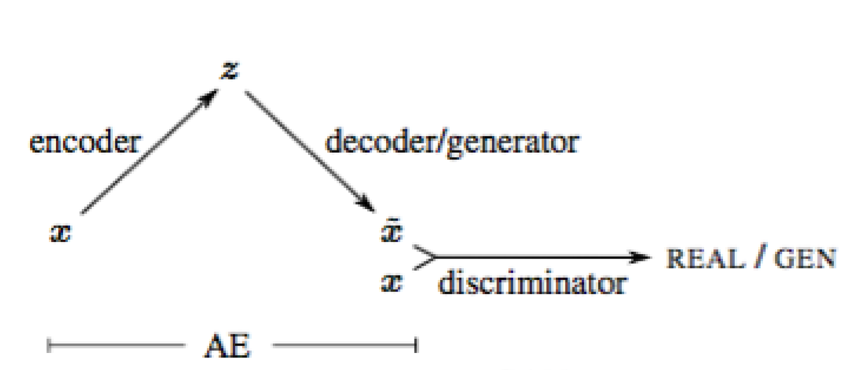
- attention-based sequential generation
- RNN structure



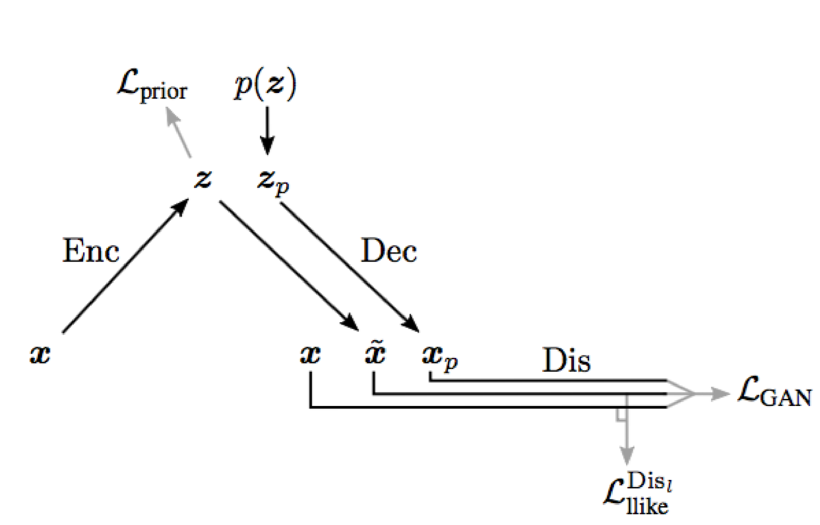


ADDING GANS

- 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

CVAEGAN results here

FUTURE DIRECTIONS

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REFERENCES

[1] Carl Doersch. Tutorial on variational autoencoders. *arXiv preprint arXiv:1606.05908*, 2016.

[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.